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# An Examination of the Natural Constraints on the Origins and Development of Darlington

## Volume I


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May 2002

This thesis is submitted in fulfilment of the requirements for the degree of Ph.D in Geological Sciences

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# ABSTRACT

A number of previous surveys of towns and cities have been attempted, some initiated by English Heritage, others by the British Geological Survey (BGS); these used existing geotechnical data to investigate the subsurface geology in those localities. This study is possibly unique, in that a more holistic approach has been made in order to investigate the origins of a medieval market town (Darlington, County Durham). In addition to the accumulation of a very large database of subsurface geological records, other data sources were also accessed, relating to the hydrological systems, archaeological evidence and extant cartographic information.

As an integral part of this study, data from some 1029 engineering boreholes were assembled, recorded, analysed, interpreted and developed into a very extensive database. Use of this new data source has resulted in a better understanding of the solid geology of this district, including the confirmation of the previously unknown Darlington synclinal structure (and its relationship to the subsurface hydrological system) and this in turn has resulted in amendments being made to the current BGS map of the area. Additionally, new large-scale drift maps and sections have been generated for the town centre area and much of the adjacent River Skerne corridor. The late Devensian drift has been shown to comprise of at least five distinct fluvio-glacial sedimentary units, a pattern of sedimentation that was echoed within the Skerne River valley, but with the addition of Holocene peat deposits.

Using GIS to graphically interpret the database information has made it possible to interpret the pre-glacial drainage pattern for the district using the rockhead map generated, also it has been possible to identify post-glacial drainage patterns in the fluvio-glacial sediments.

By combining the known cartography and town planning history with the other elements of the study, it has been possible to locate the principal areas of relatively undisturbed, partially disturbed and totally destroyed shallow deposits within the town centre area. The resulting information is considered to provide a reasonable platform for informed future archaeological management and town centre development planning.

Prediction of the location of the original settlement was found to be less certain, however, this study has highlighted the need for future new areas of research before a definitive outcome can be reached.

Conclusions are drawn into the effectiveness of the data retrieval methods used in this study and recommendations are given for future evaluation and validation work. These include the need for supplementary site investigation and testing in areas where data are sparse, the establishment of agreed strategies with public bodies and the introduction of standardised national codes for recording purposes and finally, the introduction of primary legislation to achieve these objectives.

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Finally, I owe an immeasurable gratitude to my wife Barbara for her support, sacrifices and critical contribution during the long period of producing this work.

# 1.0 - INTRODUCTION

## 1.1. Background

The aims and objectives of this study were twofold:

- To explore how the relationship between related sciences could help predict the origins and location of the early settlement of Darlington.

- To examine how the relationships impact on the modern town.

Darlington is a market town situated on the border of County Durham and North Yorkshire (NZ 430 514) given in Figure 1.1.

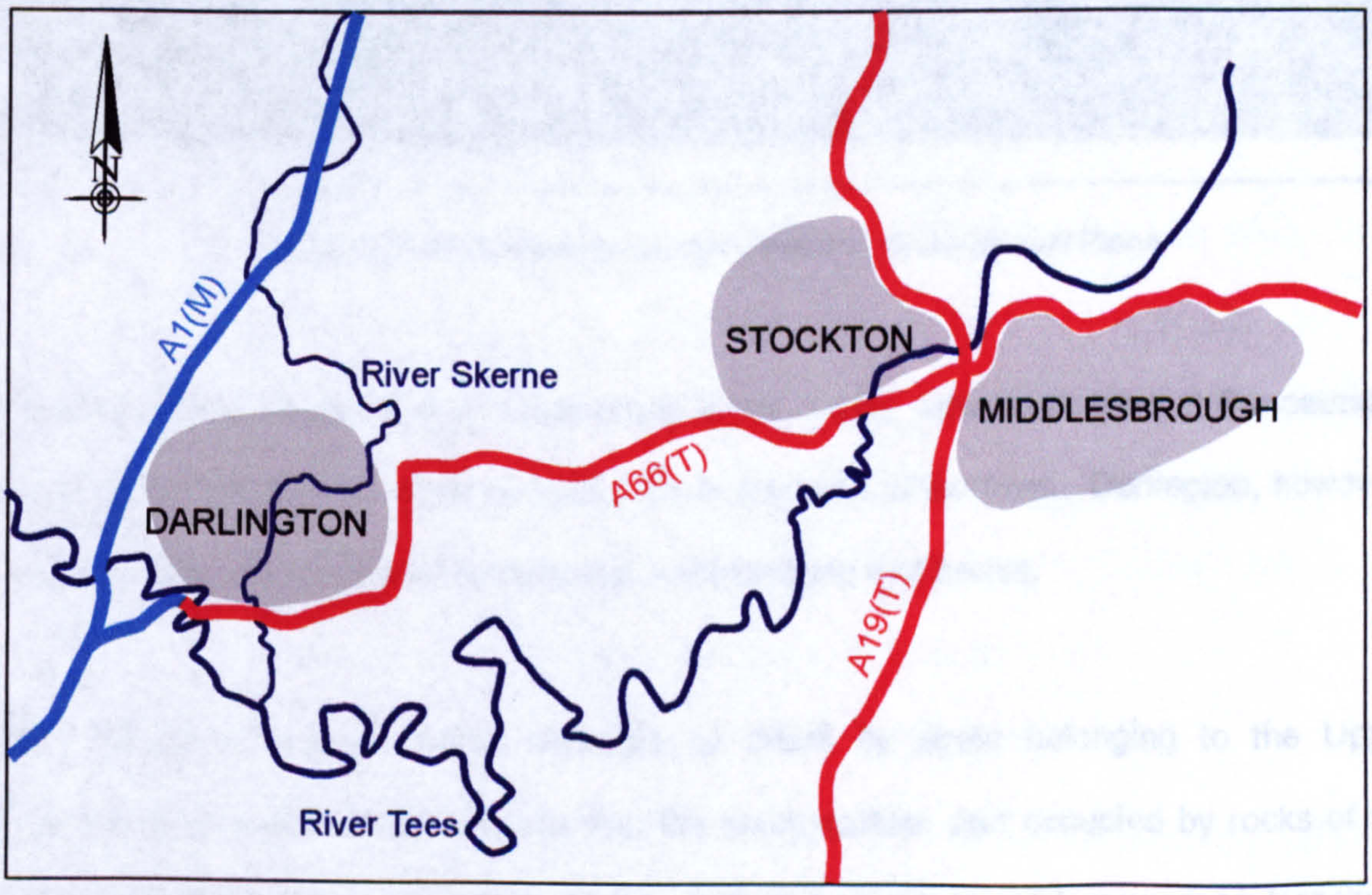



Figure 1.1 - Darlington Location Plan

The town straddles the lower reaches of the River Skerne, which is a major tributary of the River Tees. The origins of the town are uncertain. There appears to be elements of a

grid pattern of streets which suggest an early planned town origin. Such grids were common in the pre-Conquest *burgh* and the medieval planned towns of the 12th century. The town now boasts a fine market place, which is dominated on the eastern side by St Cuthbert's Church which was erected in 1194 by Bishop Hugh de Puiset.

Figure 1.2 - St Cuthbert's Church Viewed from the Market Place

Romano-British activity is well documented in the region, with major sites at Piercebridge and at Stanwick St John, both some 8.5 km to the west of the town. Darlington, however, has yielded no significant archaeological material from that period.

The Darlington area is mainly underlain at depth by strata belonging to the Upper Carboniferous and Permian Periods with the south-eastern part occupied by rocks of the early Triassic Period. The whole of the area is overlain by drift sequences largely of Quaternary and Holocene glacial and post glacial origin. The modern town takes its water supply from the main aquifer (the magnesian limestone) and the nearby River Tees.

Darlington is distinguished by the poverty of its historic sources with its first extant map of the town being that of 1826 and no firm historical reference prior to the 11th century.

## 1.2. Previous Studies

Wooler (1913) stated that excavations in Feethams Field (NZ 3290 5143) some 200 m south of St Cuthbert's Church, confirmed the presence of a *'Saxon ditch'*, a large structure measuring 2.4 m (8 ft) deep and extending to 7.6 m (25 ft) wide at the top. A map was drawn by Wooler showing his interpretation of the lines of the Saxon defences. Unfortunately, Wooler's testimony is difficult to accept since no drawings of the excavation, nor alleged finds from the ditch, appear to exist.

Two published works were applicable to this study, namely;

- the City of Durham (Lowther *et al.*, 1993) included some baseline borehole information but no attempt was made to produce sub-surface mapping, and

- the Newcastle upon Tyne Study included information on a Geographical Information System (GIS) platform incorporating the available historical/ archaeological/geological information. Unfortunately, only a small sample of borehole data was captured and this only related to the alignment of modern highways (ie A167), therefore, the study was very limited since it only referred to areas which had already been developed.

Both studies were early examples of Intensive Urban Archaeological Strategies, an English Heritage funded programme examining 30 historic urban centres, but to date, there has been no published data on the outcome of the study [Oliver, 1999].

One area where there has been some work on sub-surface mapping is in the City of London, where there is a huge amount of data together with a massive depth of archaeological deposits. Some of this information was collated in a study partly funded by English Heritage; however, it is understood that the results were not in a useable form and therefore no published documentation is yet available.

The British Geological Survey (BGS) undertook a series of Land-Use Planning Reports generally covering former coal mining areas following the demise of the industry. One study (Jackson & Lawrence, 1990) considered the area around Morpeth-Bedlington-Ashington in Northumberland (NZ 28 and NZ 38). The work involved the collation and interpretation of data from many different sources:- a specially commissioned 1:10,000 scale field geological survey, coal exploration boreholes, deep mine and opencast coal abandonment plans, site investigation boreholes and reports, existing geological maps and memoirs and other archival material held by third parties. Computerised databases of borehole and geotechnical information were established. The study obtained information from similar sources covered by this study and extended to about 1,300 boreholes and shafts in that area.

The BGS hold an extensive collection of paper records which describe the strata encountered during the sinking of boreholes, mineshafts and trial pits. The paper borehole record was considered to be the authoritative primary record and there was no attempt to replicate it on the computer. The work resulted in the establishment of a simple system by which borehole information was assigned to two tables of data.

The outputs from the various studies were a series of maps relating to drift and solid geology, together with land-use drawings, all drawn to a small scale of 1:25,000. By the nature of the large study area, the results were by necessity generalised. Furthermore, the resultant database was not as comprehensive and dynamic as those attempted by this study.

## 1.3. The Value of this Study

This study uniquely examined the four principal disciplines of geology, hydrology, topography and cartography, and assembled comprehensive data sets for each. However, geology formed the central plank of the study, and the main thrust of the investigation relies on the collection of 1029 boreholes.

The rationale adopted involves the construction of unified databases, and the assignment of accurate spatial attributes to each unit of data within each disciplinary database. The three spatial dimensions are related to the ordnance survey national referencing standards and are illustrated in Table 1.1.

| Attributes | Tolerance |
|---|---|
| National Grid Reference | Eastings and Northings were determined to 16-digit co-ordinates (within ± 1m). |
| Surface Levels | Related to Ordnance Datum Newlyn (Ground Level given to 2 decimal places; Water Levels estimated to within ± 0.1m. |

Table 1.1 - Data Attributes and Tolerances

Time, as the fourth dimension, is also examined since it has a powerful influence in masking previous developments.

## 1.4. Units of Measure

This study spanned a time period of about 250 years, from 1750 to date of recorded material. Over that period units of measurement changed several times and it was often difficult to immediately comprehend their metric equivalent. Archer (1992) alluded to this and suggested that direct conversion from imperial to metric could lead to a spurious impression of accuracy. He also suggested that, in some cases, it would also remove the

sense of poetry of the original expression - *'the Tyne rose a yard perpendicular'* is altogether more pleasing than *'the Tyne rose 0.91 metres'* - views which this author tends to share. Units encountered in this study, together with their metric conversion factors are given in Table 1.2

| Imperial Unit | Metric Conversion |
|---|---|
| **Length** | |
| 1 inch | 25.4 mm |
| 1 link (0.66 ft) | 201.3 mm |
| 1 foot (12 inches) | 305 mm |
| 1 yard (3 feet) | 910 mm |
| 1 fathom (6 ft) | 1.80 m |
| 1 pole (16½ feet) | 5.03 m |
| 1 chain (22 yards) | 20.02m |
| 1 furlong (40 rods, 220 yards) | 200.2 m |
| 1 mile (1760 yards) | 1.609 km |
| **Area** | |
| 1 acre | 0.405 hectares |
| 1 sq mile | 2.57 sq km |
| 1 rod, Perch (sq pole) | 25.27 $m^2$ |
| **Volume** | |
| 1 gallon | 4.55 litres |

Table 1.2 - Imperial Units and Metric Conversion Factors

## Nomenclature

Several disciplines with time related events were considered by this study. A simple convention has therefore been devised and consistently applied throughout the study for convenient referencing purposes. At the heart of the system is the use of superscripts for the date of the event, for example, Dmap $^{1852}$, Flood $^{1903}$ and Contour $^{1947}$ have the following meanings:

- Dmap $^{1852}$ : A map of Darlington dated 1852.
- Flood $^{1903}$ : The flood occurring in 1903.
- Contour $^{1947}$ : A generated contour map of 1947.

## 2.0 METHODOLOGY - DATA COLLECTION

The purpose of the initial assessment was to determine what factors might influence the size and location of the early settlement. Amongst many considerations, one determining factor was probably the local geology.

The first geographical map of Darlington was produced by Woods in 1826. This map shows a small settlement with a population of about 6000 (census figures for 1821 give a value of 5750) situated on the western bank of the River Skerne. The town had well defined town boundaries, beyond which lay open countryside. Examination of the street layout appears to show a typical medieval townscape centred around the Blackwellgate/Skinnergate area. Consequently, it was assumed that the early settlement was likely to lie within the town boundaries as defined by Woods (1826), an extract follows:

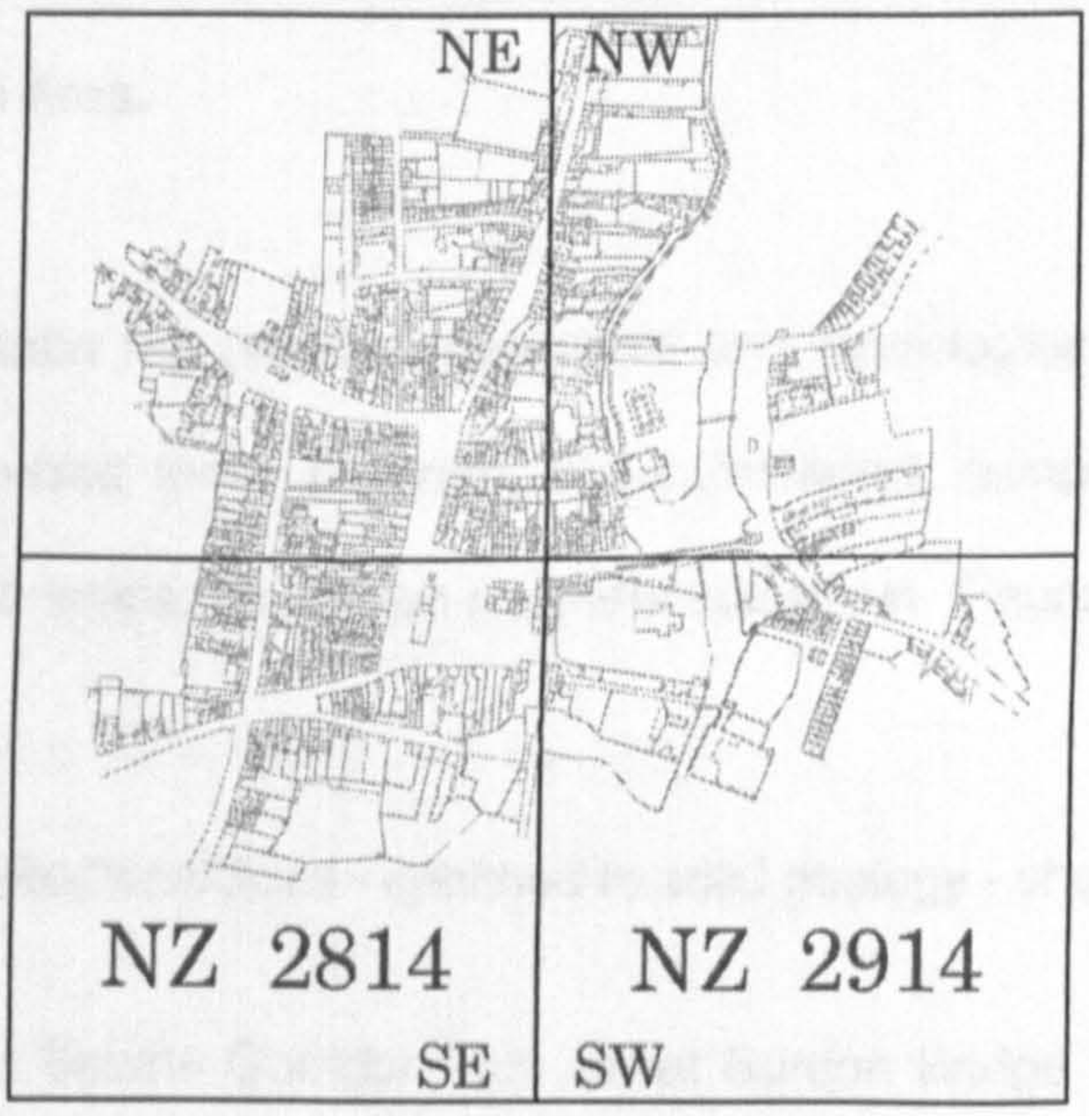



Figure 2.1 - Town Centre Scoping Area

It should be noted that the majority of the original Dmap [1826] is covered by four modern Ordnance Survey plans which also cover the existing town centre. This area was adopted as the initial Scoping Area in this research as it could be anticipated that significant

geological data could be collected from modern town centre developments. This area is referred to in this research as the Town Centre Area.

It soon became apparent that the area designated for the initial scoping exercise was inadequate as the early settlement must have been associated with the nearby River Skerne. Furthermore, the question as to whether the river was navigable is also pertinent. If it was, was the River Tees, to which the Skerne discharges some 6.4 km away, also an influencing factor? Consequently it appeared prudent to extend the scoping area to embrace the River Skerne corridor, from its confluence with the Tees (NZ 428923 510092) upstream to Great Burdon Bridge (NZ 431643 516454) - the extent of the current built-up area. This area is referred to as the River Skerne Corridor Area.

Additionally, water supply was most likely to have been a strategic factor in the siting of the early settlement. Therefore, the scope of the study was further widened to examine the solid geology and associated hydrology of the surrounding area. This area is referred to as the Sub-Region Area.

Having initially assessed the principal geological and hydrological constraints, the final Scoping Study comprised three separate, but interrelated, components. These three areas, and their relationships, are shown diagrammatically in Figure 2.2 and are;

- the Sub-Regional Area - confined to solid geology - shown yellow,
- the River Skerne Corridor from Great Burdon Bridge to its confluence with the River Tees - confined to shallow drift and alluvium deposits - shown blue, and
- the Town Centre Area - shown red.

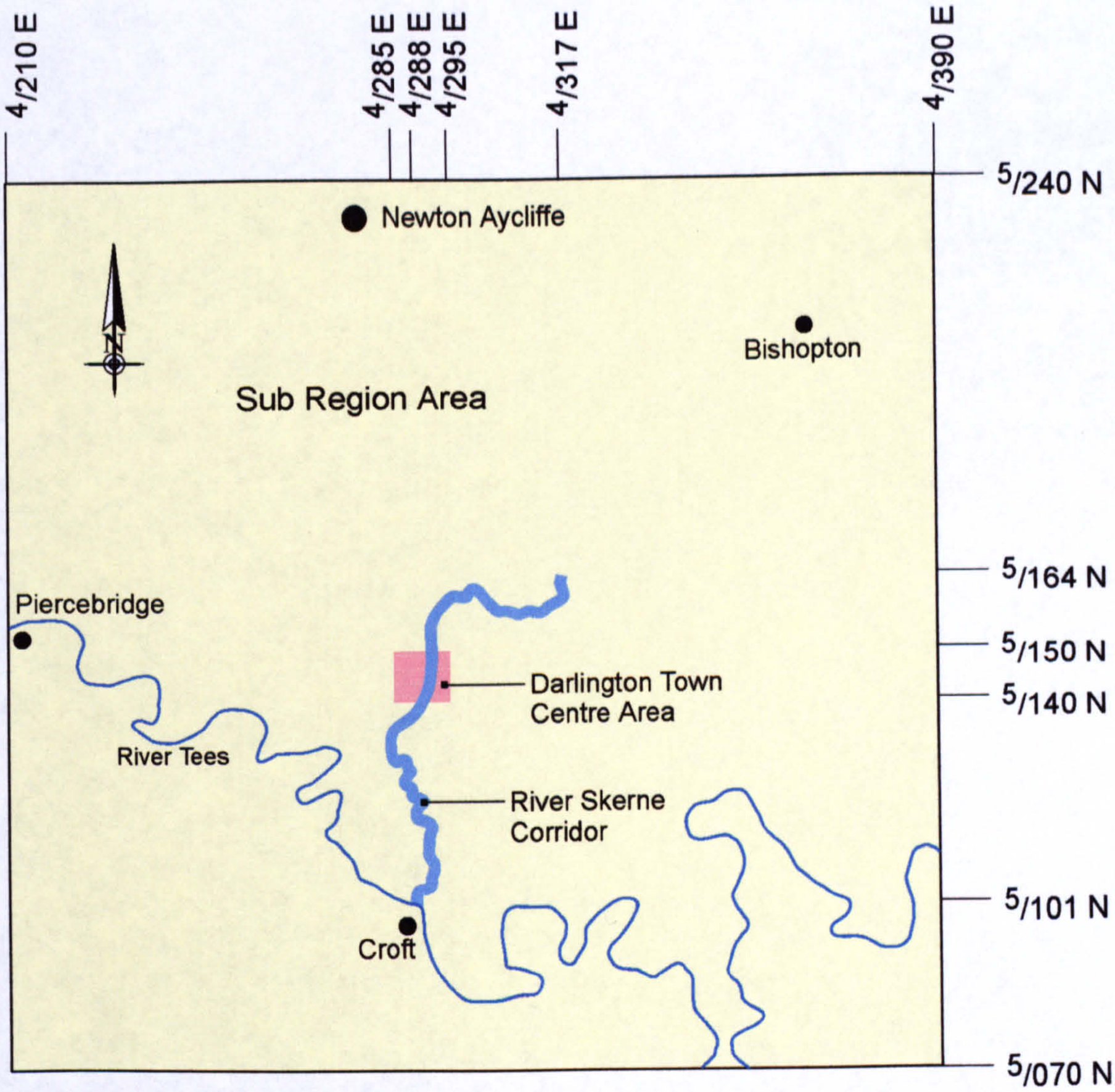



Figure 2.2 - The Scoping Areas

Data which could provide confirmatory evidence of the settlement origin and subsequent development were assembled and analysed. It was considered that the following data sources would provide a suitable platform for this investigation:

- Geology and hydrology
- Cartography
- Topography
- Flood evidence

## 2.1. How the Data were Collected

Essentially three basic categories of data were sought with the express purpose of collecting all available geological information in order to compile a single comprehensive data set. Information was available as follows;

- existing Maps.
- books and Publications.
- geological data collected personally and through professional contacts.

Maps are essential for the rapid assessment of topography and regional geology. They were used for determining the general geological conditions for the initial evaluation of ground and surface water supply potential. Reports and papers enlarged on the general information provided by the maps. However, there was no substitute for personal civil engineering field experience of the geology of the Scoping Area.

## 2.2. Likely Sources of Data

The Scoping Area laid within the boundaries of four British Geological Survey (BGS) published maps as shown in Figure 2.3.

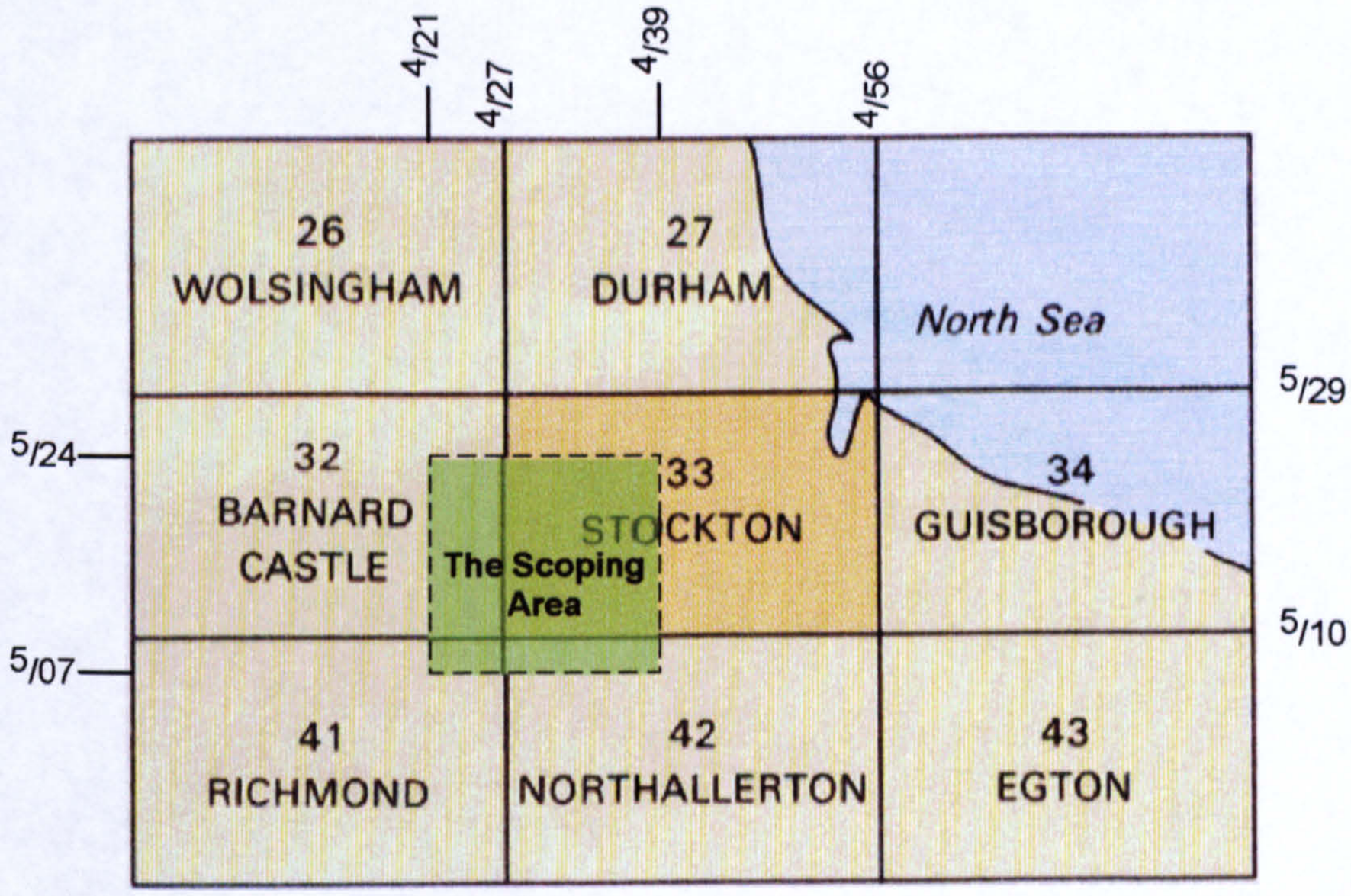



Figure 2.3 - Scoping Area in relation to BGS Map Index

The BGS maps illustrated by Figure 2.4 are the 1:50,000 series showing Solid and Drift Geology. By the nature of the scale and the limited amount of information available to the geologists responsible for this mapping, these maps should only be treated as indicative.

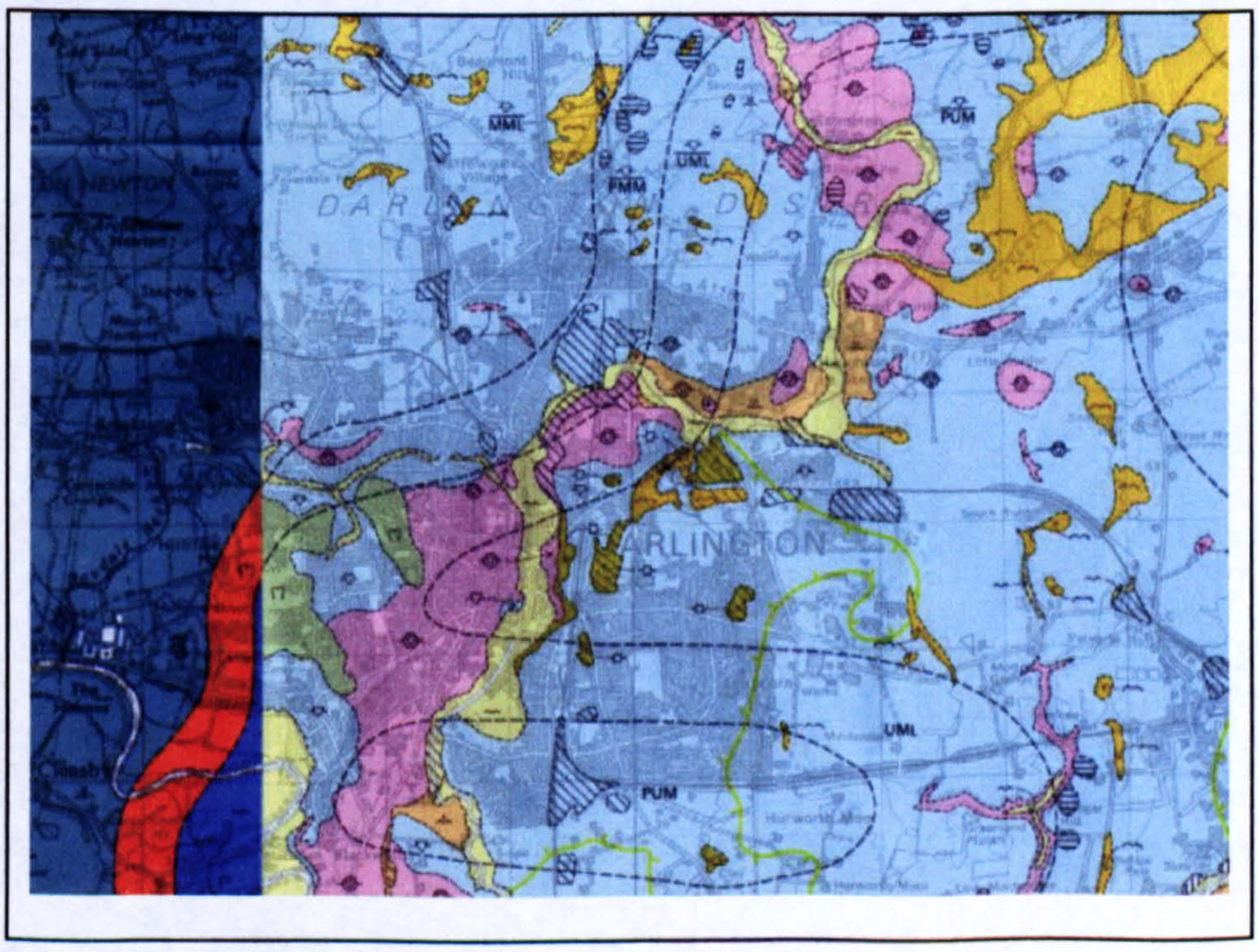



Figure 2.4 - Extract from BGS Map at 1:50,000 scale

The BGS have published three Memoir Volumes of the Geological Survey of Great Britain, all of which included parts of the Scoping Area, namely;

- *Geology of the country around Barnard Castle*, (Mills & Hull 1976),
- *Geology of the country around Thirsk*, (Powell, Cooper & Benfield 1992),
- *Geology of the country around Northallerton*, (Frost 1998), and
- *Geology of the Northern Pennine Orefield, Volume 2, Stainmore to Craven* (Dunham & Wilson 1985).

These Memoirs include a variety of maps, borehole logs and locations accompanied by photographs.

During the past thirty years, the writer has gained extensive knowledge of the shallow geology of the Scoping Area through work as a civil engineer engaged in highways, bridges and main drainage works. The last was particularly valuable with soft ground tunnelling requiring compressed air and dewatering techniques. Over this period there was considerable dialogue with other civil engineers employed in the construction industry. This personal knowledge and communication with consultants and contractors formed the backbone of the data collection process and allowed access to records otherwise unavailable to the general researcher.

## 2.3. Likely Source of Data

At the commencement of this part-time research (1995), the BGS had its regional office in Newcastle upon Tyne. However, shortly afterwards BGS rationalised its service provision and operations which led to the closure of the Newcastle office. As a result the majority of the available data was transferred to Keyworth, Nottingham with the remainder to the

Edinburgh office. Unfortunately, the available data for this study area were divided between the two offices.

Essentially BGS hold two categories of information;

- borehole logs, reports and samples in the public domain. This information can be purchased or, as in this case, made available for academic study free of charge subject to agreement.

- confidential borehole logs, reports and samples provided by various organisations usually relating to commercial interests or sensitivity.

Information can be either in published or unpublished form.

In respect of geological information, there are no statutory requirements on the construction industry to generally furnish any public body with the findings of their site investigations. The only requirement relates to explorations for water supply and minerals (including gas and oil). In this regard, the BGS has produced guidance notes setting down the statutory powers; operations covered by the appropriate Act of Parliament; duties of persons sinking boreholes, shafts and wells, together with procedures to be adopted. The publications are:

- Notification of intention to sink boreholes and shafts (BGS, 1993)

- Notification of intent to construct new wells and boreholes for water in England and Wales and the subsequent provision of information (BGS, 1992)

The first requirement, in respect of the sinking of boreholes and shafts for minerals, including petroleum, is by virtue of Section 23 of the Mining Industry Act 1926 as

amended by the Mines and Quarries Act 1954 and the Science and Technology Act 1965 and Section 9 of the Petroleum (Production) Act 1934.

The second requirement relates to the sinking of new wells and boreholes for water by virtue of S198 and S205 of the Water Resources Act 1991.

In summary, these duties were confined to:

- Notification, in writing, to BGS of the intention of sinking new wells and boreholes.
- Keep a record of the operations with details of the nature and thickness of the strata and the depth at which each bed was found. Standard record sheets are available from BGS.
- Retain specimens of the strata either as cores or fragments, for a period of at least six months.
- Allow any properly authorised officer free access at all reasonable times to any such shaft, borehole or core to inspect and take copies of the records, to inspect all cores or fragments obtained, and to take representative specimens of such cores or fragments.
- In underground workings, allow access to any properly authorised officer with the same conditions and facilities as listed above. Such officer to have the same rights as to the production and examination of plans and sections as are conferred on Inspectors of Mines.

Furthermore, the requirement is only for boreholes, shafts and wells which exceed a depth of 30m or 15m from the surface, for minerals and water respectively.

The purpose of these sections of the Acts is to ensure that all information obtained from the sinking of boreholes, shafts and wells is made available to the BGS. These data, along with the BGS data comprise a considerable volume of information of the geological

structure of this country and the nature and extent of its natural resource. Data are either published or held available for public inspection, except that information communicated as confidential is not divulged without consent.

Under these criteria, far fewer site investigations are reportable, resulting in a largely incomplete national database for borehole logs. Perhaps this may be due to a degree of complacency within the industry, despite the operation of a voluntary code existing in certain sections.

## 2.4. The BGS Borehole Database

Notwithstanding the shortcomings of the statutory requirements on the industry to deposit borehole logs and reports with the BGS, many additional voluntary submissions have been made. The vast majority of the database is manually recorded. The BGS has adopted the ¼ Sheet Ordnance Survey maps at a scale of 1:25,000 (2½ inches to one mile) to record the location of the borehole or group of boreholes with an appropriate reference number. In addition to the map an index for each ¼ sheet is maintained.

Where locations of boreholes are known, the BGS record those. Appendix 1 shows three example extracts of the database of typical location plans and the method of recording boreholes for three separate locations.

The extracts given of the Index and the location plans are from the Keyworth Office at Nottingham. It is, however, worthy of note that the Edinburgh Office employs a different method of numbering of the borehole logs. For a government scientific institution housing the national database of geological information to operate at a parochial level appears to be bizarre. Nevertheless, the data are generally available from the BGS on a commercial basis, but on this occasion it was kindly provided free of charge for the purpose of academic research.

The quality of the available borehole logs was variable, some could be read with care, others not. Similarly the commentary of the lithology was mixed whilst the information in respect of ground levels was invariably poor; the number of available boreholes, however, was relatively large.

Seven extracts giving a representative sample of information held by the BGS is given in Appendices 2-8.

The BGS database is categorised, in terms of quality, in Table 2.1.

| Quality | Borehole Log | Location Plan | Report |
|---|---|---|---|
| Good | Readable<br>Authoritative Lithology<br>NGR given<br>Ground Level given | Clear and concise | Available |
| Moderate | Readable with care<br>Reasonable lithology<br>No NGR given<br>Ground Level estimated | General location often open to interpretation | Unavailable |
| Poor | Barely readable<br>Extensive deciphering of lithology required<br>No NGR<br>No Ground Level | Location not known, restricted to locality | |

Table 2.1- Analysis of the Quality of BGS Logs

The BGS database of submitted logs only represents a minority of the boreholes sunk by the industry. If a comprehensive database was to be established, then other sources would be needed to obtain the additional information.

By the very nature of an urban settlement being established, expanded and regenerated, a vast amount of civil engineering, hydrological and building work must have been carried out. Various organisations and companies have engaged in all aspects of the construction industry, either by using in-house expertise or through appointed consultants and contractors. Site investigation is now commonplace and is an essential requirement in the consideration of proposed projects. Although not all proposals come to fruition, valuable information may have been assembled in order to have given due consideration to the validity of the proposal.

## 2.5. Additional Information Sources

The following organisations and companies all held, or have held, privately owned geological data for the scoping area. The information was found in fragmented form and generally not in the public domain.

The BGS: In addition to their submitted logs notifiable under statute, the BGS hold their own database of boreholes used to construct the geological maps and also private commissions from various sectors of the industry. Usually the latter information is held on a confidential basis and is therefore unavailable. The BGS deep boreholes, whilst fewer in number, are often very deep, penetrating various horizons within the solid geology. Commentary and classification are authoritative. The locations and related ground levels, however, were often estimated. In the case of the boreholes drilled for the purposes of Mineral Assessment, boreholes are usually shallow with good location but estimated ground levels.

Local Authorities: These bodies were the principal developers of the urban area dating back to Victorian times. Their functions included housing, highways, sewerage and sewage disposal, water supply and education, in addition to owning numerous public buildings of all types. Some of these functions have subsequently transferred outside

their direct control but often archives remain. In the case of Darlington Borough Council, it holds incomplete records for elements of all of these functions from the nineteenth century. Furthermore, the record was mainly uncatalogued and fragmented between engineering, architecture, planning, building control and environmental health departments.

Site Investigation Companies held a significant and valuable amount of data, invariably retained on a confidential basis for clients. Notwithstanding this constraint, by reference to the local authority planning and building regulation applications, client particulars are in the public domain. Approaches, initially to clients other than Site Investigation Companies, proved productive. Companies such as Wimpy Laboratories held a database available for purchase. Other companies directly connected to local authorities and water companies, demonstrated a willingness to co-operate. The standard of information was similar to that of the BGS submitted logs.

Public Utility Companies, including electricity, gas, water, telephone and cables were poor sources of information since the distribution systems were laid to very shallow depths of less than 1.20m. However, where buildings such as sub-stations, telephone exchanges and pumping stations were required, site investigations had usually been carried out. The water companies were an exception to the general rule because of their main drainage function. New drainage schemes nearly always had the benefit of a site investigation. Furthermore, in cases of water supply, deep borings had often been carried out. Whilst few in number, usually the interpretation of geological data, particularly the solid geology, had been done in collaboration with BGS. Overall this standard of information was similar to the BGS submitted logs.

Consulting Engineers, Architects and Environmentalists have been engaged in nearly all aspects of civil/structural and building projects and hold a significant amount of geological information. Latterly, many reclamation and regeneration projects have been subject to

additional site investigation concerning landfill gas and pollutants arising from previous land uses.

Developers of industrial, commercial and housing sites collected and acquired geological data as part of the project management process. Often the data were minimal or superficial, just sufficient enough to assess the commercial viability of a project or for tendering purposes. On other occasions, detailed site investigations were available for projects that were constructed.

The Environment Agency (formerly the National Rivers Authority) had responsibility for the issuing of water extraction licences and water supply had a wealth of good quality boreholes into the solid geology. As with the Water Companies these deep boreholes were analysed in collaboration with the BGS. Generally these boreholes are few in number of known location and estimated ground levels.

The Mining Industry, formerly the National Coal Board (NCB) and now private companies, had good detailed deep boreholes. Although relatively few in number the information was considered accurate enough to base commercial decisions upon. Locations and ground levels were good for modern working but less so for earlier workings.

Gas and Oil Companies have carried out extensive geophysical and borehole exploration work over vast tracts of the country. However, whilst it was known that this work had been carried out within the study area, this was not available for commercial security reasons.

Quarrying Companies have extensive information for specific areas. One quarry, Stonegrave Quarries, operating in the north of the scoping area, made their entire database available for this study. Tilcon, operating in the south, made some previously

confidential boreholes available. In both cases the lithology was authoritative and accurate information in respect of ground levels and locations was provided.

Large national retailers took a responsible approach to their project management by commissioning appropriate site investigation companies. Marks & Spencer and Comet for example, made information available on request.

Civil Engineering and building companies, both of national and local standing, held information on an individual project basis and contributed to the compilation of the database.

Government Departments, such as the Highways Agency (HA), Property Services Agency (PSA) and the former British Rail (BR) all had geological records relating to their works. Information was, however, located in offices outside the region but was made available.

Albeit not directly applicable to this study, extensive information was offered by the Port Authority via personal communication. It is likely that the former British Waterways and Airport Authorities held some relevant information.

From the borehole logs collected, it can be stated that the quality was variable and the logs were generally deficient in spatial information. Although access was good and co-operation high, not all information was retrieved since;

- data were retained on a confidential basis, usually for commercial reasons, but sometimes for unexplained company policy, and
- many data had been lost and destroyed. The apparent reason for this was twofold;

⇒ some data were discarded because the project did not go ahead or the owner of the data had been unsuccessful in a bidding process.

⇒ archive storage was at a premium and it appeared that with each company merger, move of offices or reorganisation, the archive had been progressively lost or decreased.

The vast majority of data collected was in paper form, usually photocopies or second photocopies of originals. Sometimes, information was also extracted from engineering drawings and microfiche. Only occasionally were the data available in digital format, and when they were, they related to the most contemporary investigations.

It became apparent that due to the perceived need for commercial confidentiality or the lack of a comprehensive recording system, many sites had been drilled several times - one site was found to have been drilled on seven separate occasions. Clearly this not only represents a waste of precious funding, but is a serious indictment of the management of this national resource.

## 2.6. Standardisation of the Data

Having collected 1029 borehole logs, in a variety of formats and to varying quality for the scoping area, it was necessary to consider how the information could be presented in standard form.

The British Standards Institute (BSI) issued BS5930 : 1999, *Code of Practice for Site Investigation (formerly CP 2001).* This document represents good practice for the industry, not only for procedures for site investigation of ground conditions, but also the recording of findings and results. In respect of borehole logs, the code states that on the issue of the method of presentation of the data, there can be no hard and fast rules. In principle, the borehole logs should give a picture in diagrams and words of the ground

profile at the particular point where the hole was bored. The extent to which minor variations in soil and rock types should be recorded, together with any discrepancies and discontinuities, will depend on the various purposes for which the information will be used.

All borehole logs are therefore a compromise between what it is desirable to record and what can be accommodated. The code states that the general data given below should be common to all logs (Table 2.2).

| | |
|---|---|
| • Title of investigation<br>• Report number<br>• Name of Client<br>• Location detailed by a grid reference<br>• Date of boring<br>• Borehole number and sheet number, eg sheet 2 of 2<br>• Type of boring, eg cable percussion or rotary | • Make of plant used<br>• Ground level related to Ordnance datum<br>• Diameter of borehole<br>• Diameter of casing and depth to which taken<br>• A depth scale such that the depth of sampling tests and change in strata can be readily determined<br>• Depth of termination of borehole |

Table 2.2 - General Information to be included in Borehole Logs

Additionally the ground profile should be illustrated by means of a legend using recommended symbols. Apart from the symbols, the code makes no recommendations for the many other requirements for the preparation of the borehole logs. The code continues to the effect that many different types are in use, and provided an adequate key is given with every set of borehole logs, there should be no difficulty in interpreting them.

In addition to the 'legend information' referred to above, the code suggests the information given below should be recorded for Light Cable Percussion boring (Table 2.3).

| | |
|---|---|
| • A description of each stratum together with its thickness.<br>• The depth and level of each change of stratum.<br>• The depth of the top and bottom of each tube sample, or bulk sample and its type. The depth of each small disturbed sample.<br>• The depth at the top and bottom of each borehole test and the nature of the test.<br>• Where standard penetration tests are being recorded, tests made with the thick-walled sampler should be distinguished from those made with a solid 60º cone. Where it has proved impossible to drive the sampler the full 450mm required for the test, this should be stated. No SPT value as such should be recorded, but only a note of the total penetration achieved with the total number of blows applied. | • The date when each section was bored.<br>• A record of each water strike, including rate of rise of water level, depth of water in the borehole at start and finish of shift, and the depth of casing when each observation was made.<br>• A record of any water added to facilitate boring.<br>• Where observation wells or piezometers have been installed, their depths should be given, together with details of the installation, preferably in the form of a diagram.<br>• Water levels in observation wells measured subsequent to the completion of the borehole, unless recorded separately. |

Table 2.3- Additional Information to be included in Borehole Logs for Light Cable Percussion Boring

Similarly for Rotary Drilling, the additional information should be recorded (Table 2.4).

| | |
|---|---|
| • A description of each stratum together with its thickness.<br>• The depth and level of each change in stratum.<br>• The depth of the start and finish of each core run.<br>• The core recovery for each run, usually expressed as percentage total core recovery (TCR).<br>• The fracture state, expressed in terms of one or more of the following: rock quality designation (RQD), solid core recovery or fracture log.<br>• The date when each section of the core was drilled.<br>• An indication of the drilling-water recovery for each core run, with note on any change in colour. | • A record of the depth of water in the hole at start and finish of shift and the depth the casing, where used, at the time the observations were made.<br>• A record of any observation wells or piezometers which were installed with a note of their depths together with details of the type, preferably in the form of a diagram.<br>• Water levels in observation wells measured subsequent to the completion of the drillhole unless recorded separately.<br>• A record of tests carried out, such as permeability and packer tests.<br>• The orientation of the drillholes. |

Table 2.4 - Additional Information to be included in Borehole Logs for Rotary Drilling

The code sets standards for new work, directly under the control of the investigator. However, no control was exercisable over the historic data collected; nevertheless compiling a standard log irrespective of the range of data available was possible. The devised log, given in Appendix 9 was based upon the good practices advocated by the code and incorporates the salient features recommended, albeit some entries remain silent in many cases.

All the borehole information was then copied onto the standard format log; however, this proved to be somewhat ambitious since much of the information sought simply did not exist. A revised log was therefore adopted for the final outputting of geological data and a typical example is given at Appendix 10.

## 2.7. Referencing System

Having commented on the shortcomings of the BGS parochial referencing systems, it was important from the outset to determine the criteria for a referencing system of all data and generated information covered by this study. The key elements for the system included the following data requirements:

- Universal in nature.
- Logical and appropriate.
- Compatible with Geographical Information Systems (GIS).
- Compatible with the Ordnance Survey Digital Mapping System.
- Capable of electronic downloading to Computer Aided Design (CAD) packages in AutoCAD.
- Rapid retrieval ability.

These requirements lead down the route of adopting co-ordinates based upon the national grid as the central plank of the referencing system. It also followed that a computerised data storage system was needed. A thorough understanding of the national grid reference system was also needed.

## 2.8. Storage of the Data

In respect of the geological data, there appeared to be two data storage options, namely:

- Develop a bespoke program especially for this project, or
- Use a preparatory commercial package.

To develop a bespoke program was not deemed to be a viable option, because of the time and expertise needed. The decision was, therefore, taken to use a proven branded product capable of meeting all of the criteria outlined. Key-Systems had long been a market leader in engineering software packages which were not only standalone products, but were capable of interfacing with AutoCAD. The company marketed a package known as HoleBASE, a database designed specially for geological information. Over the duration of the study revised and improved versions were issued, culminating in HoleBASEII, which was adopted for the final presentation of outcomes. HoleBASEII is a database configured in such a way that each Site Investigation project has a separate collection of data tables in its own sub-directory (folder). It had the capacity to store an infinite number of projects.

The system operators used AGS Data Format which is a system derived and regulated by the Association of Geotechnical & Geoenvironmental Specialists, which was the standard method of transferring geotechnical and geoenvironmental data from ground investigations between organisations. Widely used in the UK, it also had growing

currency abroad, principally in the Far East, but also to some extent in the United States and parts of continental Europe. The format was devised and regulated by the Association of Geotechnical & Geoenvironmental Specialists, an independent trade organisation based in the United Kingdom. The format and rules can be found in the publication: 'Electronic Transfer & Storage of Geotechnical Data from Ground Investigations', (AGS, 1994).

AGS data can be both imported and exported, and the system would accept data from Excel (.xls files) spreadsheets. Additionally, data could be transported to other packages, ie AudoCAD, which allowed the creation of plan production, section plotting, boundaries and surface modelling.

The primary output from HoleBASEII was borehole logs, which could be constructed to bespoke requirements.

HoleBASEII needed at least the following PC operating platforms (Figure 2.5).

| | Minimum | Optimum |
|---|---|---|
| Operating System | Windows 3.x | Windows 95/NT |
| Processor | 486 DX33 | P133 |
| RAM | 16 MB (8 MB for Windows 3.x) | 32 MB |
| Free Disk Space | 50 MB | 100 MB |
| Free Base Memory | 590 KB | 600+ KB |
| Printers | LaserJet III or equivalent | LaserJet 5M or equivalent |

Table 2.5 - PC Platform Consideration for HoleBASE II

## 2.9. Creating a Record

HoleBASEII is organised into a hierarchical family structure of parent and child records. To create a new set of records for a site investigation, the following procedure was strictly followed.

The Project Manager facility was the control plank of the system. It enabled new projects to be created, prevented access by more than one user at a time to a particular project and informed on the status of projects. Additions and deletions were managed via Project Manager. Most importantly it ensured that each project had been assigned a unique identity and incoming electronic data could not be written to the incorrect database. An extract from Project Manager is shown in Figure 2.5.

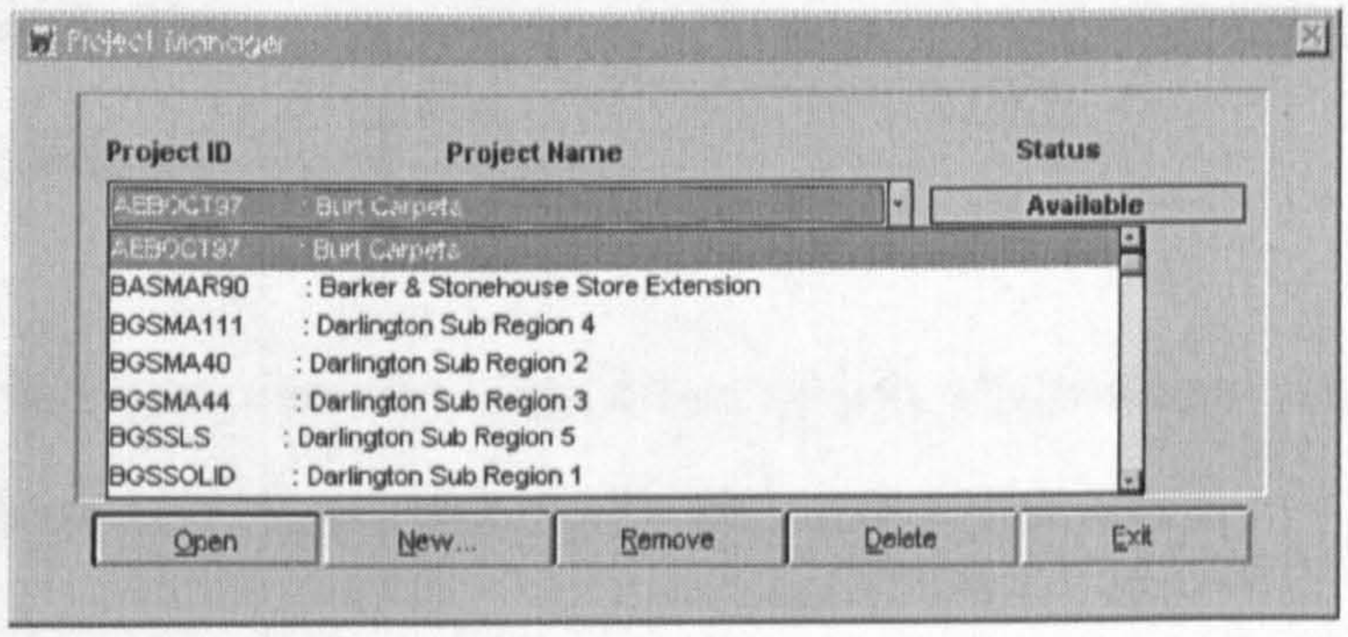



Figure 2.5 - Extract from HoseBASE II Project Manager

It was essential to assign a unique project identity, not only because HoleBASE II denied access to duplications, but also for good housekeeping purposes. The system devised comprised a unique eight character alphanumeric reference (the maximum allowable by the program). This was appropriate to the project name, and the date of the investigation, and comprised three individual components as illustrated in Table 2.6.

| Reference | Explanation |
|---|---|
| BAS | An abbreviation, for Barker & Stonehouse store extension - the full Project name. |
| MAR | The month in which the original Site Investigation was carried out. |
| 90 | The abbreviation of the year (19)90 in which the original Site Investigation was carried out. |
| BASMAR90 | The full Project Reference. |

Table 2.6 - Explanation of Project Reference

Whilst the referencing system worked well, the obvious limitation relates to the data element, since the abbreviation for the year (90) occurs each century. In practical terms, however, this was not seen as a problem because of the other two prefixed. Rarely it may be necessary to search the database for two dates in the fullness of time - should the system gain universal acceptance. If a totally unique system, irrespective of time, was required either HoleBASE could be modified to accommodate a 10 character alphanumeric reference, or the month (MAR) could be modified to (A-L) and the year (90) modified to (1990) and so on. Nevertheless, the referencing system devised for this study worked perfectly well.

Once a project had been correctly named and logged, the Program presented the user with a window requesting Project Information as shown in Figure 2.6.

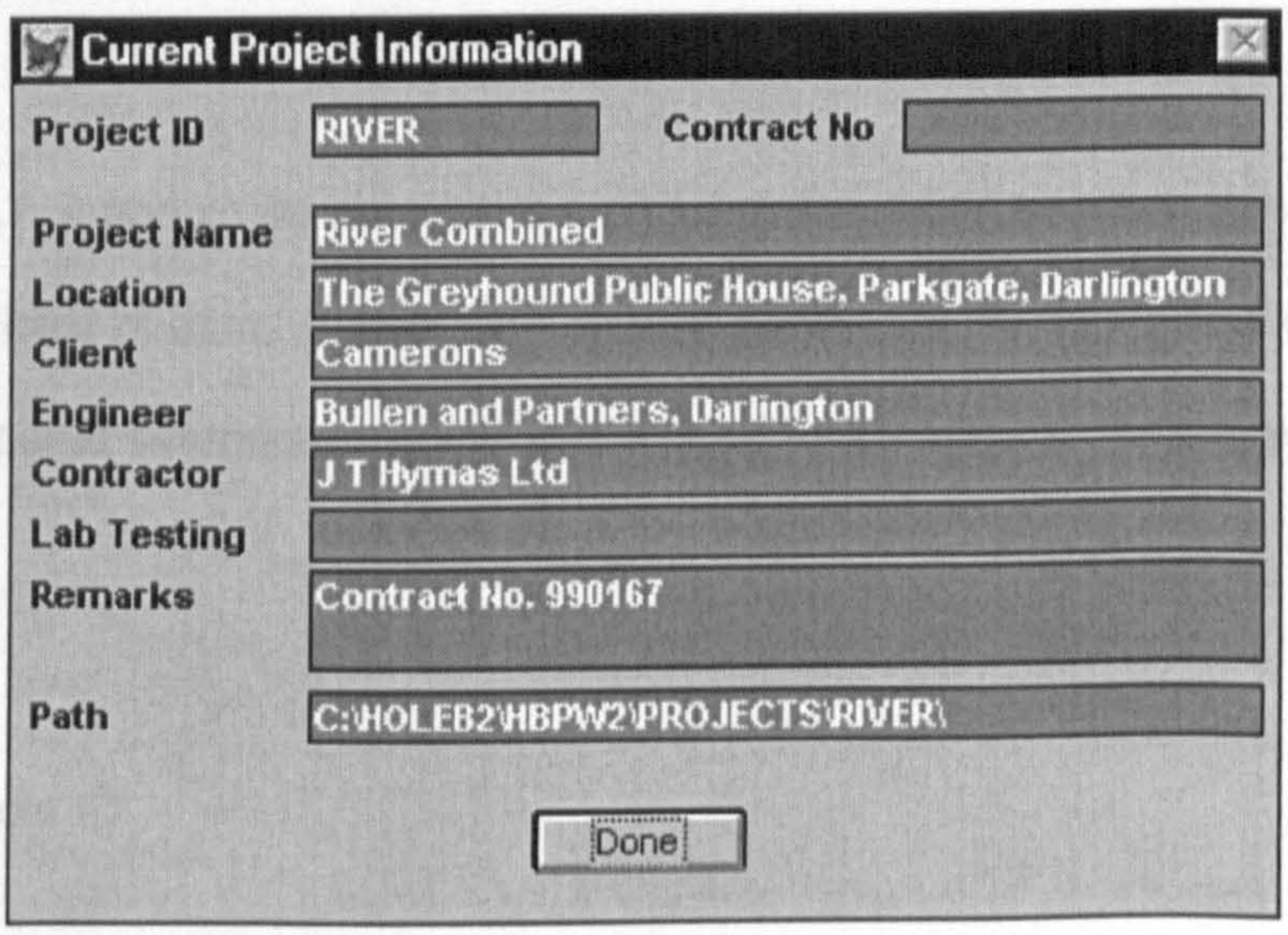



Figure 2.6 - Extract from HoleBASE II Project Information Window

Often, not all of the data were available to complete the Project Information Window. In such cases all available information was recorded.

The data tables in HoleBASE II were linked together in a parent-child relationship. The Parent Record related to an individual borehole and comprised a comprehensive set of attributes as shown in Figure 2.7.

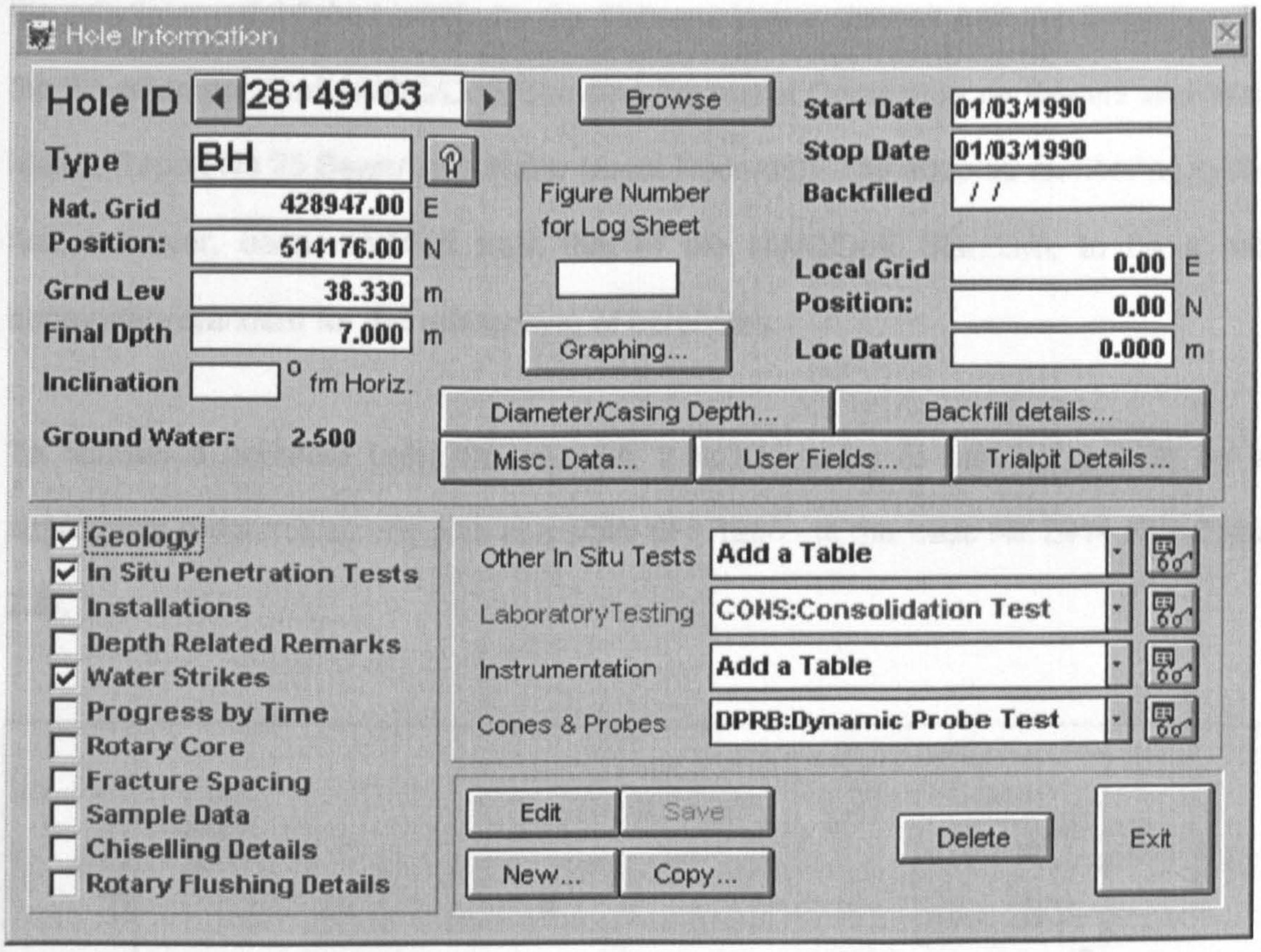



Figure 2.7 - Extract from HoleBASE II, Hole Information Window

From Figure 2.7, it should be noted that the Hole Information window presents numerous alphanumeric fields of data. Some fields were essential for plotting purposes, others were useful for additional information which was logged when known. The essential elements were:

- Hole ID
- NGR Position
- Ground Level (m AOD)

It was important that the numbering system adopted for the Hole ID was valid for at least the extent of the scoping area and ideally should possess a universal capability to accommodate future expansions. Each borehole has been assigned an eight figure number, based upon its geometric position within the 100m square of the National Grid. In this case, the square prefixed by the letters NZ. The numbering system is based upon

the principles established jointly by the National Water Council and the Department of the Environment (Ref : NWC/DoE Standing Technical Committee on Sewers and Water Mains, Report No 25 Sewer and Water Mains Records). The adopted numbering system has, however, been modified from that of the NWC/DoE Standard, to be a more appropriate standard for the referencing of boreholes.

To number a borehole using this system, it is necessary to plot its position on the appropriate ordnance survey plan at a scale of 1/1250 - in this case NZ 2914 NW (Figure 2.8).

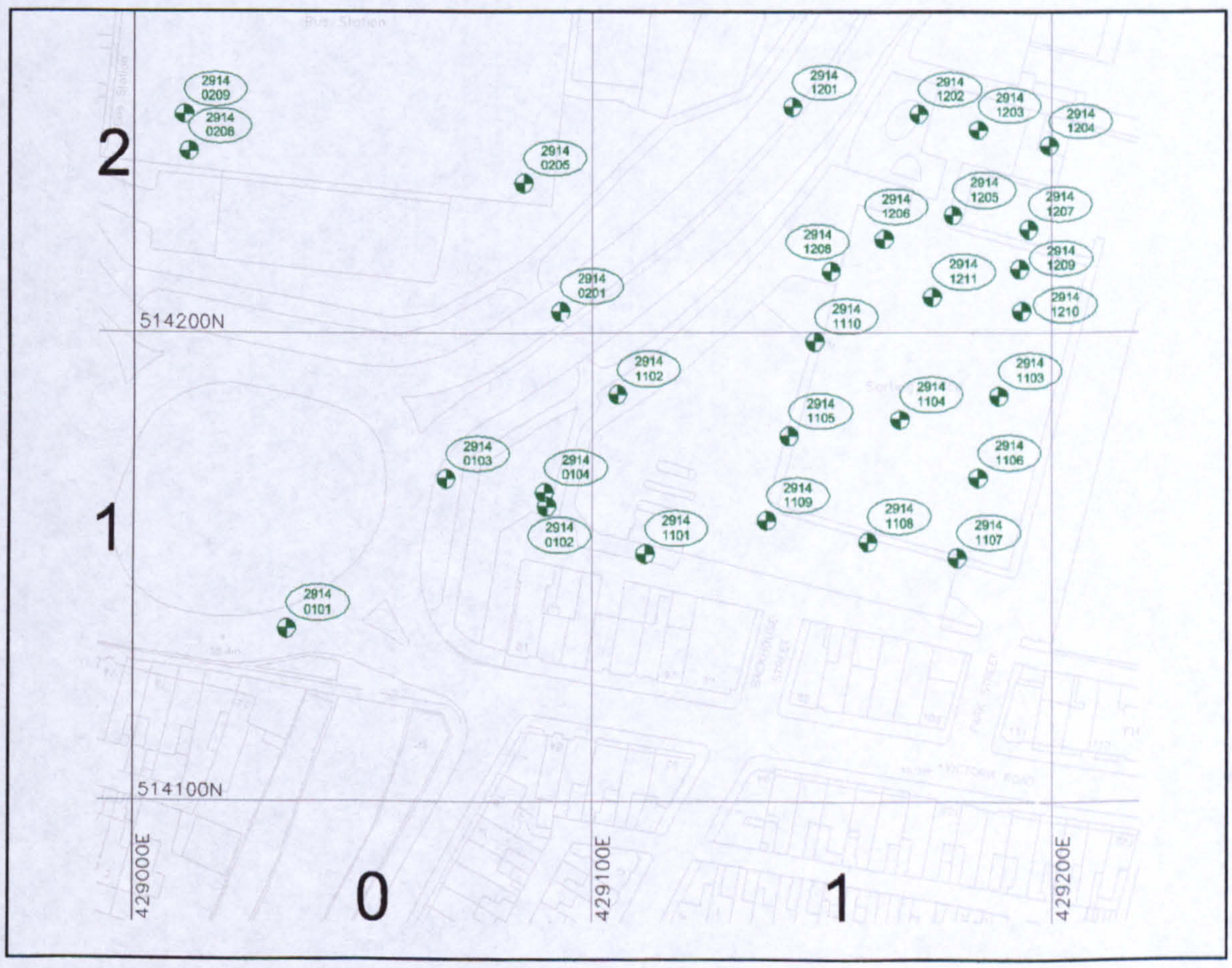



Figure 2.8 - Extract from OS NZ 2914 NW showing borehole numbers

The eight figure Hole Identification Number comprises four individual components, as described in Table 2.7.

| Hole ID | Explanation |
|---|---|
| 2914 | An abbreviation for Ordnance Survey Sheet NZ 2914. |
| 0 | The value of the easting within the 1000m square. |
| 4 | The value of the northing within the 1000m square |
| 04 | The number assigned to the borehole within each 100m square (ie 01, 02, 03, 04 .... 99). |
| 29140404 | The adopted Hole Identification Number |

Table 2.7 - Explanation of Hole ID Numbering System

There are limitations with the eight figure numbering system. Although valid within a 100km square, there are many other like squares within the National Grid (see Figure 2.9). Consequently for a unique Hole Identification Number, it is necessary to extend the number to ten characters, to include the relevant two letter prefix, ie NZ 29140404. This alphanumeric style would be important when considering the labelling of boreholes at the 100km square boundaries, or if a very large data set was being handled.

For the sake of clarity, it was elected here to adopt the abridged eight figure number version, by removing the two letter prefix since all boreholes were located within the same 100km square.

The eight figure number has another inherent limitation. By definition, the maximum number of boreholes that can be uniquely labelled within a 100m square, is 99. In practical terms, however, the system is likely to have sufficient capacity even for the most intensely investigated areas. In this Study, the maximum number of boreholes recorded within a 100m square was eleven. Should the maximum number of 99 be exceeded, the Hole Identification Number could commence with a second series, say in italic type.

The National Grid Position: For plotting purposes and interfacing with other packages, full national grid referencing (NGR) in terms of eastings and northings was required.

Assigning NGR to each borehole was a major task. Figure 2.8 shows typical base recording plans and illustrates the degree of difficulty. In the first instance all known or assumed positions of the boreholes were plotted manually onto the relevant ordnance survey plan at a scale of 1/1250. A large degree of judgement was exercised using this process as contradictory or duplicated information was often encountered. There was frequent need to refer to other sources of information, such as contract documents (when available), drawings or notes. Rarely was the precise location defined, particularly within the overall Region Scoping Area. More confidence could be attributed to the Town Centre Area since the location of many boreholes was constrained by existing features such as roads, rivers and buildings. Once plotted it was then a relatively simple task of measuring the values of the co-ordinators, albeit by hand. Toward the end of the Study, when a full integrated GIS was available, each set of co-ordinates was checked and amended or confirmed by use of the electronic measuring tools. It was necessary to fix the co-ordinates of a borehole position before it could be assigned a Hole Identification Identity because of the protocols adopted for the referencing system. The program allowed for local grid positions, but this was not used.

The Ground Level was the third essential spatial dimension required for section plotting. Furthermore, it needed to be expressed with respect to ordnance datum. As with the fixing of the NGR co-ordinates, very little information was available as originally collected. The vast majority of boreholes were either lacking on this issue or a level had been estimated. In order to fix reasonably the ground level to ordnance datum it was necessary to refer to;

- ordnance survey sheets both early and late editions,
- relevant engineering drawings,
- contract documents, and

- actual site conditions.

In the case of the formal supporting documentation, this was rarely available, but it was invaluable when it was. Exceptionally it was necessary to use a surveying instrument to determine the relevant level. The exercise of fixing ground levels to the 1029 boreholes within the study area was a massive but nevertheless essential undertaking, for the production of authoritative outcomes.

Other miscellaneous information such as dates, backfill details, diameter of holes/casings etc were logged when known.

A series of Child Records was provided with HoleBASE II. Each topic had its own specialised window with similar layouts and actions. Not all Child Records could be completed because of the lack of information, but as with the Parent Records, available data were recorded. Typically, the records available included available parameters (Table 2.8).

| Description | |
|---|---|
| Backfill Details (BKFL) | Water Readings |
| Diameter/casing with Depth (HDIA) | Depth Related Remarks (DREM) |
| Geology Records (GEOL) | Water Strikes (WSTK) |
| Description Detail (DETL) | Progress by Time (PTIM) |
| Weathering (WETH) | Rotary Core Records (CORE) |
| In situ Penetration Tests (ISPT) | Fracture Spacing (FRAC) |
| Incremental Blows Counts | Chiselling Record (CHIS) |
| Installations (PREF) | Rotary Flushing Records (FLSH) |

Table 2.8 - Available Child Records, HoleBASE II

The most important Child Records were the Geology Records (GEOL) together with the Description Detail (DETL) and Legend Code.

Figure 2.9 shows the structure of the geology window; the principal elements used were;

- the base depth of each stratum,

- the stratum description, as recorded on the original documentation. The only difficulty here was the deciphering of the original data. However, it became apparent that different drillers/geologists had varying interpretations of what was probably the same stratum. At this stage, no attempt was made to co-ordinate and standardise descriptions - merely a faithful record was made,

- Geology Code, not used in this case but typically, Fill, Alluvium, Organic Soils, Glacial Till, Sedimentary Rock, Igneous Rock and Metamorphic Rock, and

- Legend Code, HoleBASE II included a standard set of bitmap hatching patterns, 160 entries in total, which were assigned numeric codes. The program allowed the user to create additional hatching patterns. The library compiled to BS 5930.

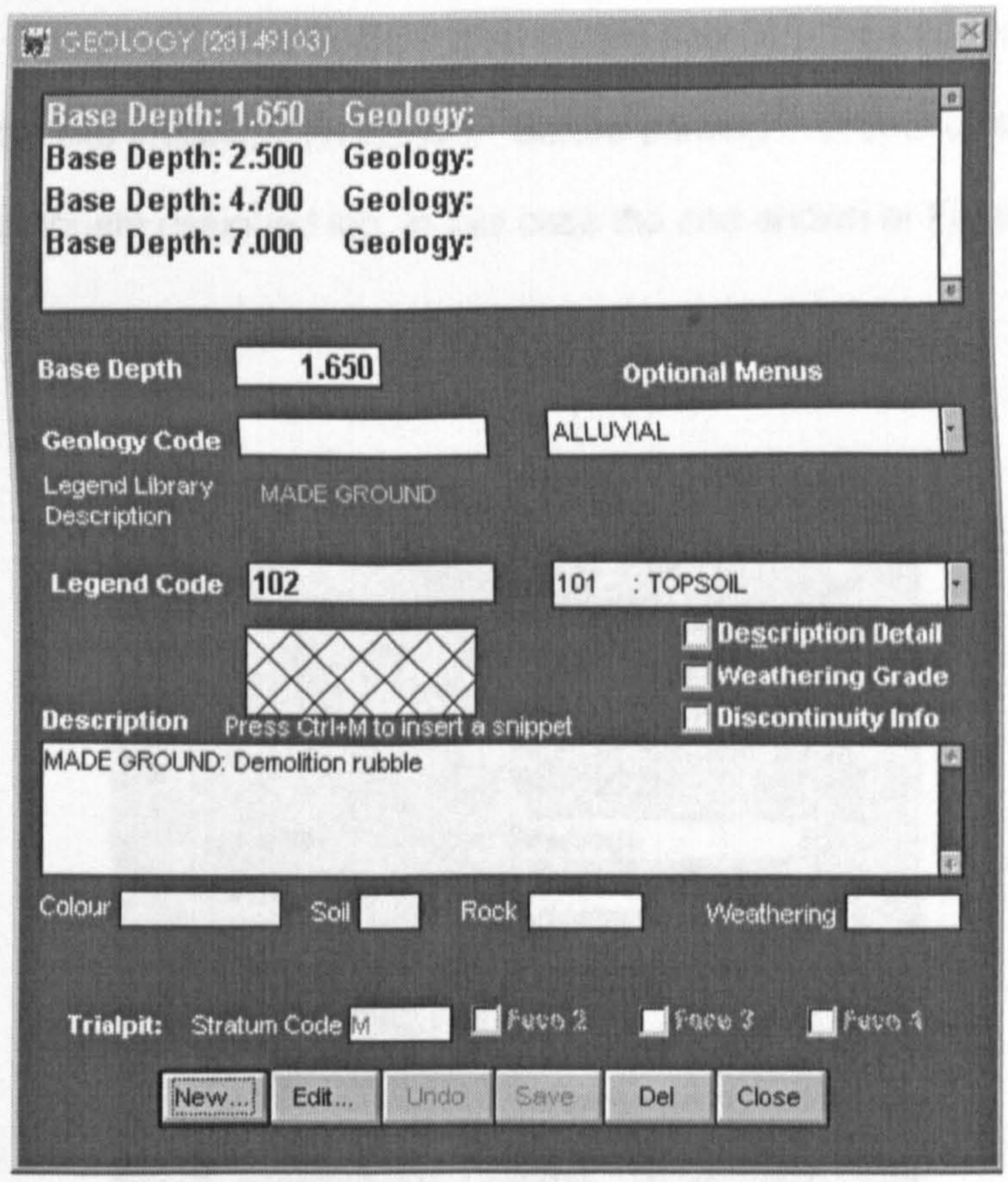



Figure 2.9 - Extract from HoleBASE II, Geology Window

Once the data were captured, it was necessary to produce the initial output - the borehole log; again this was achieved by further commands to the program (Figure 2.10).

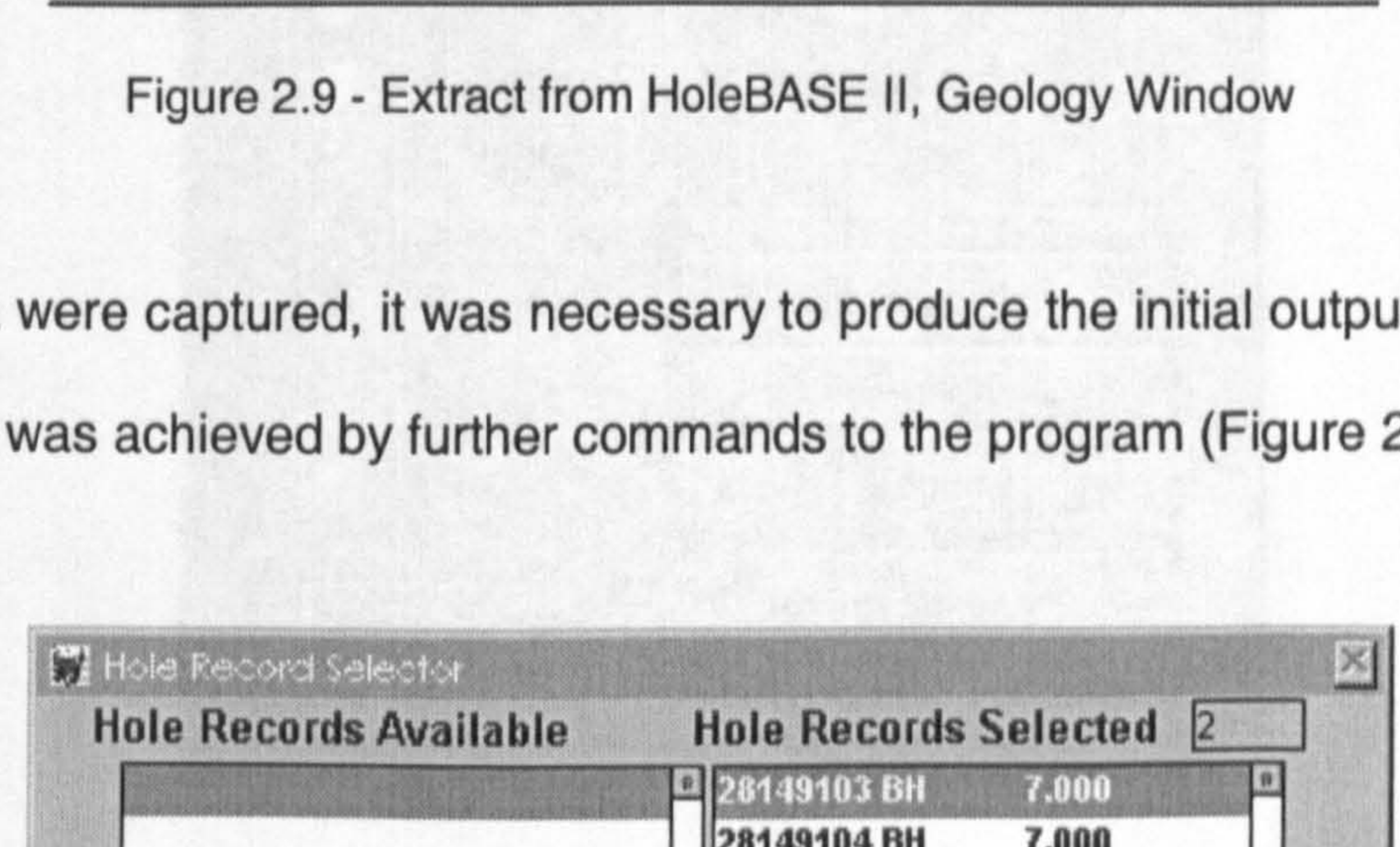



Figure 2.10 - Extract from HoleBASE II, Hole Record Selector Window

As illustrated in Figure 2.10, HoleBASE II allowed the user to print either individual logs or a series within the site investigation project. Before printing proceeded, it was necessary to select the appropriate designed log, in this case the one shown at Figure 2.11, labelled 13 DEC Type 1.

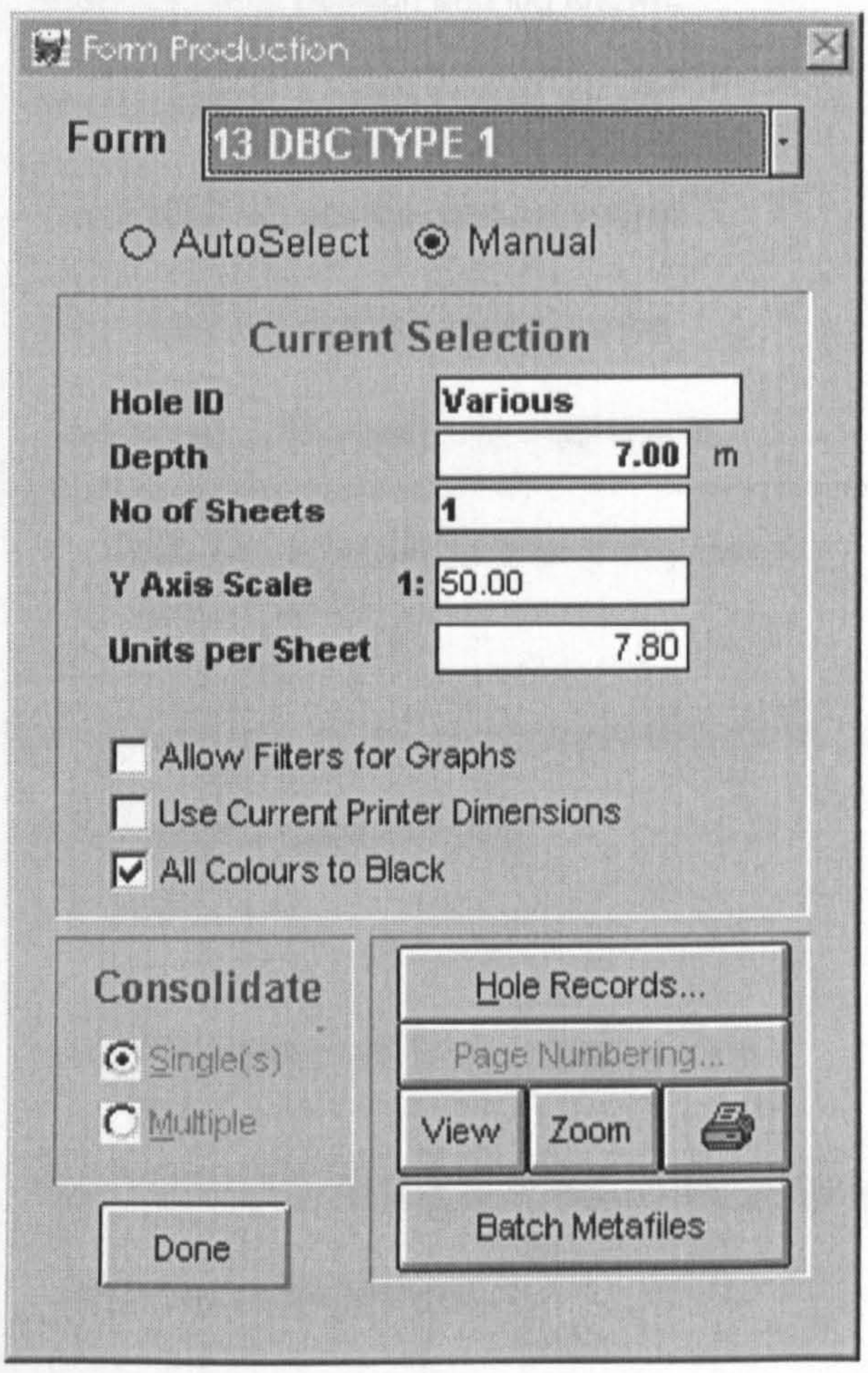



Figure 2.11 - Extract from HoleBASE II Form Production Window

The borehole logs, printed to a vertical depth scale of 1.50, were used later in the production of longitudinal sections illustrating the ground conditions. A typical example of the final logs produced is given in Appendix 10.

In addition to producing standardised borehole logs, it was necessary to record the location. The co-ordinates were used to plot the borehole position onto an ordnance survey base plan.

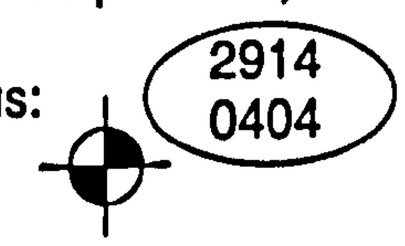
Throughout this Study, the following symbols have been adopted to represent the various exploratory holes excavated during the various site investigations (Table 2.9).

| Symbol | Explanation |
|---|---|
| | Borehole (BH), position and log known. |
| | Borehole (BH), position known, no log. |
| | Trial Hole (TH), position and log known. |
| | Trial Hole (TH), position known, no log. |
| | Trial Trench (TT), position and log known. |

Table 2.9 - Symbols for Exploratory Holes

In order to present the information in an easily readable form, the Hole Identification Number was split into two separate parts, namely;

- 2914 - the abbreviated OS Sheet number, and
- 0404 - local easting, northing, and the individual borehole number within the 100m square.

The split number is then enclosed with an elipse and positioned (as far as possible) to the top right of the borehole location (denoted by the assigned symbol) thus: 


It was, however, not always possible, or desirable, to maintain this standard throughout if there were several boreholes in a congested location, or if there were important features at the map location. An example of the final presentation map developed for borehole locations is given in Figure 2.12.

Figure 2.12 - Extract from Map Showing Borehole Positions and Numbers

## 2.10. Data Collected and Stored for the Solid & Drift Geology for the Sub Region

Having collected and standardised the boreholes for all three scoping areas, the information was entered into a geological database utilising Key Systems, HoleBASEII Software. In respect of the solid geology, the logs include their full lithological descriptions and data fields that can be exported to spreadsheet packages. The numbers and grid references of all the holes that encountered solid rock were exported to Excel and additional columns of information input by the writer to identify rockhead and to classify the solid rocks in the area. The database was modified by Dr A H Cooper (BGS) for this study based on background knowledge of the geological sequence in the area, as a prelude to a joint BGS publication by Dr Cooper and the author.

The borehole data were examined initially using the MapInfo Geographic Information System (GIS) and subsequently ArcView GIS with bespoke British Geological Survey software that allowed a revised digital version of the geology to be constructed. The initial

sweep through the data involved identifying the geology at rockhead and adding a column to the spreadsheet to show the formation using the standard British Geological Survey lexicon codes for the formations. This was then plotted as a thematic layer, coloured by formation to compare the newly interpreted geology with the existing geological maps. These were scanned and used as a backdrop to the borehole information. Numerous boreholes with interpretations that disagreed with the map were then immediately obvious.

The spreadsheet data also allowed the OD levels of the top contacts of the various formations to be compiled. This information was then plotted for five key levels and printed alongside the coloured borehole data showing the formation at rockhead. The OD levels for the tops of the formations were then contoured by hand and the geology reinterpreted to produce structure contours on maps for the area. These were projected up dip to rockhead and intersected with the rockhead contour information, also derived automatically from the GIS packages. Combining the formation at rockhead data from the boreholes, with the intersection data from the rockhead and structure contours, allowed the projected contacts of the formations to be constructed.

The structure contours were plotted for five levels in the area and a revised geological map produced by ArcView GIS using the British Geological Survey Geological Spatial Database (GSD) to capture the information. Plots at 1:100,000 scale were produced on A3 format and some larger plots at 1:50,000 were plotted using a Versatec plotter.

The resultant generated drawings are given in Chapter 3.0.

The generated drawings also include generalised information in respect of the drift geology for the sub region scoping area, but the drift is considered in greater detail in respect of the town centre. Only the interpretation of the solid geology was done in collaboration with Dr A H Cooper.

## 2.11. The Drift Geology for the Town Centre & River Corridor

The superficial geology within the town centre and in the river corridor scoping area was treated in a similar manner to that of the solid geology. The spread of boreholes within the town centre was at a considerably higher density than the sub region and therefore greater detail was achieved. Darlington Borough Council's ArcView GIS interfacing with Excel Spreadsheets, Keyhole and AutoCAD 2000 were used to capture the information. Plans at 1:1250 scale or greater were produced on A1 format using a Hewlett Packard Design Jet 800 PS plotter. In practice it was found that only limited sections of the river corridor could be drawn because of the sparcity of boreholes in the more rural areas (Table 3.5).

## 2.12. Structure

The geology data were marshalled into three separate databases which followed the same format of the scoping areas, namely;

- Darlington Town Centre comprising 335 boreholes,
- the River Skerne Corridor, from Great Burdon Bridge to its confluence with the River Tees comprising 454 boreholes, and
- the Sub-Region Area comprising 240 boreholes.

Appendices 11-13, tabulate the site investigation projects obtained for each scoping area by Project Reference. The principal characteristics of each borehole with site investigation projects is also included:

- Borehole ID number.

- Co-ordinates to the national grid.
- Ground levels relative to ordnance datum.
- Depth of borehole.

There was an element of overlapping of information between the three databases.

## 2.13. Archaeology

Darlington is distinguished by the poverty of its historic sources up to the end of the medieval period (Carne & Adams 1994). Only six recorded archaeological investigations have taken place:

- Darlington Market Place, 1994, Archaeological Services, University of Durham (ASUD 306) & Archaeological Recording, 1997 (ASUD 421).
- River Restoration Project, 1995, Northern Archaeological Services (NA 95/12).
- Palaeoenvironment Investigation at the Skerne Valley Railway Bridge, 1995, Northern Archaeological Services (NAA 95/29).
- Archaeological Monitoring at Bondgate, Darlington, 1997, Archaeological Services, University of Durham (ASUD 426).
- Commercial Street, Darlington, Archaeological Assessment and Evaluation, 2001, Archaeological Services, University of Durham (ASUD 844).
- Clark's Yard, Darlington, 1992, Archaeological Assessment, The Archaeological Practice, University of Newcastle upon Tyne.

Two further studies are applicable:

- Darlington : A topographical study, 1978 (Clack & Pearson).
- Greenbank Cemetery, Darlington, 1976 (Miket & Pocock)

The extent of the findings can be summarised;

- three flints were discovered in the Market Place, two of which are provisionally thought to be of Mesolithic or Neolithic date (Carne and Adams 1994).
- the present western churchyard wall to St Cuthbert's Church is probably sited on the edge of a river terrace (Carne and Adams 1994).
- 31 graves were excavated in the Market Place, probably from the 11th - mid/late - 14th centuries (Carne & Adams, 1994).
- a Saxon church may have stood in the vicinity of the Market Place (Carne & Adams, 1994).
- Darlington has yielded no significant material of the Romano-British period (Clark & Pearson, 1978).
- there was a Saxon settlement at Darlington, since a 19th century excavation on the Greenbank Estate site yielded six graves of 6th to 7th century date (Miket & Pocock, 1976).

## 2.14. Cartography

A general overview of the known maps of Darlington was undertaken and assembled into five main groups:

- Information catalogued in the publication 'Local History Guides - Darlington Maps & Plans' obtainable from the Darlington Reference Library, Local History Department. Where quoted, the Library's reference is provided, ie U418a.40.

- Early published Maps of Darlington.
- Darlington Local Board of Health Plan.
- The Ordnance Survey Plan.
- Engineering drawing (1852).

The Local History Guide had only catalogued a few maps, some of them the whole town, others of parts only. The relevant maps are tabulated in Table 2.10.

| Map | Description | Date |
|---|---|---|
| JEFFREY ... | Plan of County Durham | c1770 |
| MOWBRAY, J | Plan of the Revd Mr Sisson's Estate called 'High Parks' in the Township and Parish of Darlington (to the west of Neasham Road). | 1776 |
| RICHARDSON, R | Plan of Low Parks in Darlington, belonging to the Bishop of Durham (adjoining River Skerne, opposite St Cuthbert's Church). | 1788 |
| MOWBRAY, J | As Plan of the High Parks at Darlington belonging to the Lord Bishop of Durham on lease to the Revd Mr Sissons. | 1789 |
| MOWBRAY, J | A plan of Feethams belonging to the Bishop of Durham In lease to Mrs Lumley. | 1789<br>13 September |
| PEASE, E | A survey (of parcels of land in Darlington). | 1792<br>12 March |

Table 2.10 - Early Plans Listed in Local History Guide

Jeffrey's map of Durham, dated c1770 gave an indicative layout of the town of Darlington. The town was shown to be located on the west bank of the River Skerne. Whilst the map was small scale, it appeared that Darlington was centred around the Market Place and

bounded by Houndgate, Skinnergate, Northgate, Priestgate and the river. Beyond the town limits lay open countryside with the odd ribbon development on the approaches from the village of Haughton and Banktop House (Neasham Road/Yarm Road). This analysis is an interpretation of the map, an extract of which is given in Figure Appendix 14.

John Mowbray's survey of High Parks, drawn in 1776 to a scale of 5 chains to one inch (1:1320) showed the extent of land belonging to the Revd Mr Sissons. A copy of the survey is given in Appendix 15.

Fields within the holding were numbered from 1 to 18 and a table giving the names of tenants and the area of land each formed in acres, rods and poles was included, which is reproduced in Table 2.11.

| Reference | | | | | New Purchase | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | Tenant | A | R | P | No. | 30th Sept. 1784 | A | R | P |
| 1 | ? | 2 | 3 | 30 | | J. Smurthwaite | | | |
| 2 | Do .. | 3 | 0 | 08 | | | | | |
| 3 | Thos. Shaw | 3 | 3 | 34 | | | | | |
| 4 | Wm. Lutey | 4 | 2 | 09 | 8 | | 3 | 0 | 00 |
| 5 | Do ... | 3 | 2 | 36 | 9 | | 2 | 2 | 00 |
| 6 | Geo Johnson | 6 | 0 | 21 | 10 | | 2 | 2 | 00 |
| 7 | Do ... | 5 | 3 | 33 | 11 | | 2 | 1 | 24 |
| **Yellow** | **Total** | **30** | **1** | **11** | **Green** | **Total** | **10** | **1** | **24** |
| | | | | | 12 | | 2 | 2 | 01 |
| Other parts of Smurthwaite's Farm in red | | | | | 13 | Orchard | 0 | 1 | 12 |
| (Nos 12-18) | | | | | 14 | | 2 | 2 | 23 |
| | | | | | 15 | | 3 | 1 | 08 |
| | | | | | 16 | | 3 | 3 | 08 |
| | | | | | 17 | | 4 | 2 | 32 |
| | | | | | 18 | | 3 | 1 | 08 |
| | | | | | **Red** | **Total** | **20** | **2** | **12** |

Table 2.11 - Mowbrey's Survey 1776, Revd Sissons Land Holdings giving Tenants and Areas

The names of adjacent landowners and the extent of their holdings, as far as they abut High Parks, is also given - Table 2.12.

| Approximate Position | Comment |
|---|---|
| To the West<br>• Abutting High Parks<br>• Abutting River Skerne | The Bishop of Durham - the Low Park Estate<br>Miss Lumley (Feethams) |
| To the South West | General Lambton (Polam) |
| To the South | James Allan |
| To the East<br>• From South to North | Thos Lewis/Newby Lawson/Robt Ward/Newby Lawson/Burrill |

Table 2.12 - High Parks 1776, Land Distribution

Indicative sketching of Blackwellgate and Horse Market are shown with what appears to be a series of field boundaries immediately south of this ribbon development.

Richardsons' survey of Low Parks, drawn in 1788 to a scale of two chains to one inch (1:528) showed the extent of land belonging to the Bishop of Durham (adjoining the River Skerne). A copy of the survey is given in Appendix 16. Richardson's survey followed a similar presentation style to that of Mowbray with the name of the tenant given together with the area of each field in acres, rods and poles. This information is reproduced over in Table 2.13.

| Summary | | | | | | |
|---|---|---|---|---|---|---|
| Lessee | Each Close | | | Lesses Total | | |
| | A | R | P | A | R | P |
| Richd Thompson | 1 | 2 | 24 | | | |
| | 1 | 3 | 16 | 3 | 2 | 00 |
| Thos Stokell | 1 | 2 | 30 | | | |
| | 1 | 2 | 24 | 3 | 1 | 14 |
| John Kendrew | 3 | 0 | 20 | | | |
| | 3 | 2 | 06 | 6 | 2 | 26 |
| Joh,an Backhouse | 2 | 1 | 36 | | | |
| | 3 | 1 | 24 | 5 | 3 | 20 |
| Mrs Elz Lumley | | | | 5 | 1 | 00 |
| | | | | 24 | 2 | 20 |

Table 2.13 - Richardson's Survey 1788, Bishop of Durham's Land Holding giving Tenants and Areas

Richardson's survey showed the River Skerne, the road to Yarm 10 miles (16 km) (now Parkgate) and the bridge over the river. Other features could not be read.

The names of adjacent landowners and the extent of their holdings, as far as they abutted Low Parks, were also given and shown in the Table 2.14.

| Appropriate Position | Comment |
|---|---|
| To the East | High Park leasehold under the Bishop |
| To the West of the River Skerne | Feetham's leasehold under the Bishop |

Table 2.14 - Low Parks 1788, Land Distribution

Pictorial representations of St Cuthbert's Church and the nearby school were depicted on the survey presumably at the appropriate locations.

John Mowbray produced a second survey, drawn in 1789 to a scale of 3 chains to an inch (1:792), of the High Parks Estate in respect of land belonging to the Lord Bishop of

Durham on lease to the Revd Mr Sissons (Appendix 17).

As before, Mowbray numbered the fields and parcels of land from 1 to 10 and recorded the area of each envelope in acres, rods and poles. This information is reproduced in Table 2.15.

| No. | Area | | | Area | | | Occupier |
|---|---|---|---|---|---|---|---|
| | A | R | P | A | R | P | |
| 1 | | | 20 | | | | |
| 2 | | 1 | 28 | | | | |
| 3 | | 1 | 04 | | | | |
| 4 | | | 29 | | | | |
| 5 | 1 | 2 | 04 | | | | |
| 6 | 5 | 2 | 06 | | | | |
| 7 | 4 | 0 | 08 | | | | |
| 8 | 4 | 0 | 16 | 16 | 0 | 35 | In Miss Lumley |
| 9 | 3 | 3 | 16 | | | | |
| 10 | 3 | 1 | 22 | 7 | 0 | 38 | In Thos. Naylor |
| | | | | 23 | 1 | 33 | Total |

Table 2.15 - Mowbray's Survey 1789, Bishop of Durham's Land Holding giving tenants and areas

The names of adjacent landowners and the extent of their holdings, as far as they abutted High Parks (Table 2.16).

| Approximate Position | Comment |
|---|---|
| To the east of River Skerne | The Low Park belonging to the Bishop of Durham in lease to Mrs. Lumley. James Backhouse, John Kendrew, Thomas Stockill, Richard Thompson. |
| To the east of River Skerne, south of Low Park, opposite boundary of Feethams Fields 8 and 9. | The High Park belonging to the Bishop of Durham in lease to Rev. Mr. Sissons. |
| To the west | General Lambton |
| To the west<br>North of General Lambton's enclosures about mid-way of Feethams Field No. 7 | Joseph Alan Esq. |
| To the north<br>West of Feetham Track | The Earl of Darlington |
| To the north<br>West of River Skerne | Bishop's Palace |

Table 2.16 - High Parks 1789, Land Distribution

The location and shape of the former Bishop's Palace, labelled 'now Old Hall' is shown in this 1789 survey.

The survey of land belonging to Edward Pease Esq, was drawn in 1792 to a scale of two chains to one inch (1:528). It shows the extent of the land bounded by the Mill Dam and Freemans Place (Appendix 18).

Again the names of adjacent landowners and salient features, such as roads and bridges, together with field numbers and acreages, are given and reproduced (Table 2.17).

| Ref | Description | Area | | |
|---|---|---|---|---|
| | | A | R | P |
| 1 | Road - Durham Road/Mill Dam | 0 | 0 | 25 |
| 2 | Field - Northgate/Mill Dam | 0 | 2 | 31 |
| 3 | Mill Dam | 0 | 0 | 26 |
| 4 | Field | 2 | 2 | 0 |
| 5 | River Skerne | 0 | 1 | 35 |
| 6 | Field | 2 | 2 | 21 |
| - | Land sold for building ground | 0 | 2 | 35 |
| 7 | Field No 513 (17.6) | 0 | 3 | 31 |
| 8 | Field No 507 (£7) | 2 | 3 | 14 |
| 9 | Field No 508 (£8) | 3 | 0 | 25 |
| 10 | Orchard | 1 | 0 | 17 |
| 11 | Field, with stream feeding River Skerne | 5 | 0 | 30 |
| 12 | Garden with dwelling | 0 | 1 | 10 |
| 13 | Garden attached to 12? | 0 | 0 | 15 |
| 14 | Field | 1 | 1 | 37 |
| 15 | Steam feeding River Skerne | 0 | 2 | 24 |
| 16 | Field | 0 | 1 | 36 |
| 17 | Field | 2 | 1 | 31 |
| 18 | Field | 0 | 1 | 32 |
| 19 | Rood | 0 | 1 | 8 |
| 20 | Field | 0 | 3 | 22 |
| 21 | Field | 4 | 1 | 36 |
| 22 | Field No 489 (8.15.0) | 3 | 3 | 15 |
| 23 | Field | 3 | 2 | 2 |
| | Grand Total | 39 | 1 | 38 |
| | Less land sold for Building Ground (No 19) | 0 | 2 | 35 |
| | Nett Total | 38 | 3 | 03 |

Table 2.17 - Pease Plan 1792, Land Use and Areas

Published maps of Darlington have only been available since 1826, when John Wood produced the first known map of town to a scale of 2 chains to 1 inch (1:528). The Woods map (Dmap [1826]) covers the Town Centre Scoping Area. It showed streets, buildings and watercourses and its general coverage is shown in Appendix 19.

Updating of the town map was carried out by Anthony Reed in 1829 (Dmap [1829]) drawn to a scale of one chain to one inch (1:264) and comprised two maps and a schedule. At one time the original map of the built-up area of Darlington had been mounted on a plywood board, encased in a glass frame and displayed in full sunlight in the Town Hall at Darlington. Presumably, this act of municipal vandalism occurred prior to the opening of the public building in 1970! Also displayed within the same frame was a schedule of owners and tenants (Plate 2.2). A photographic extract of Reed's map and his schedule is given at Appendix 20.

The finding of the original copy of the *'Darlington Local Board of Health Plan of the Town of Darlington'* was a major discovery of cartographical evidence. The map comprised a series of 31 hand drawn maps to a scale of 44 ft to 1 inch (1:528) together with a cover sheet bearing the title and date. The series was prepared from a survey by Messrs. Herbert, Fawcett and Barker, and referenced for the purposes of the study Dmap [1852]. No index was included with Dmap [1852], but one was assigned (Figure 2.13).

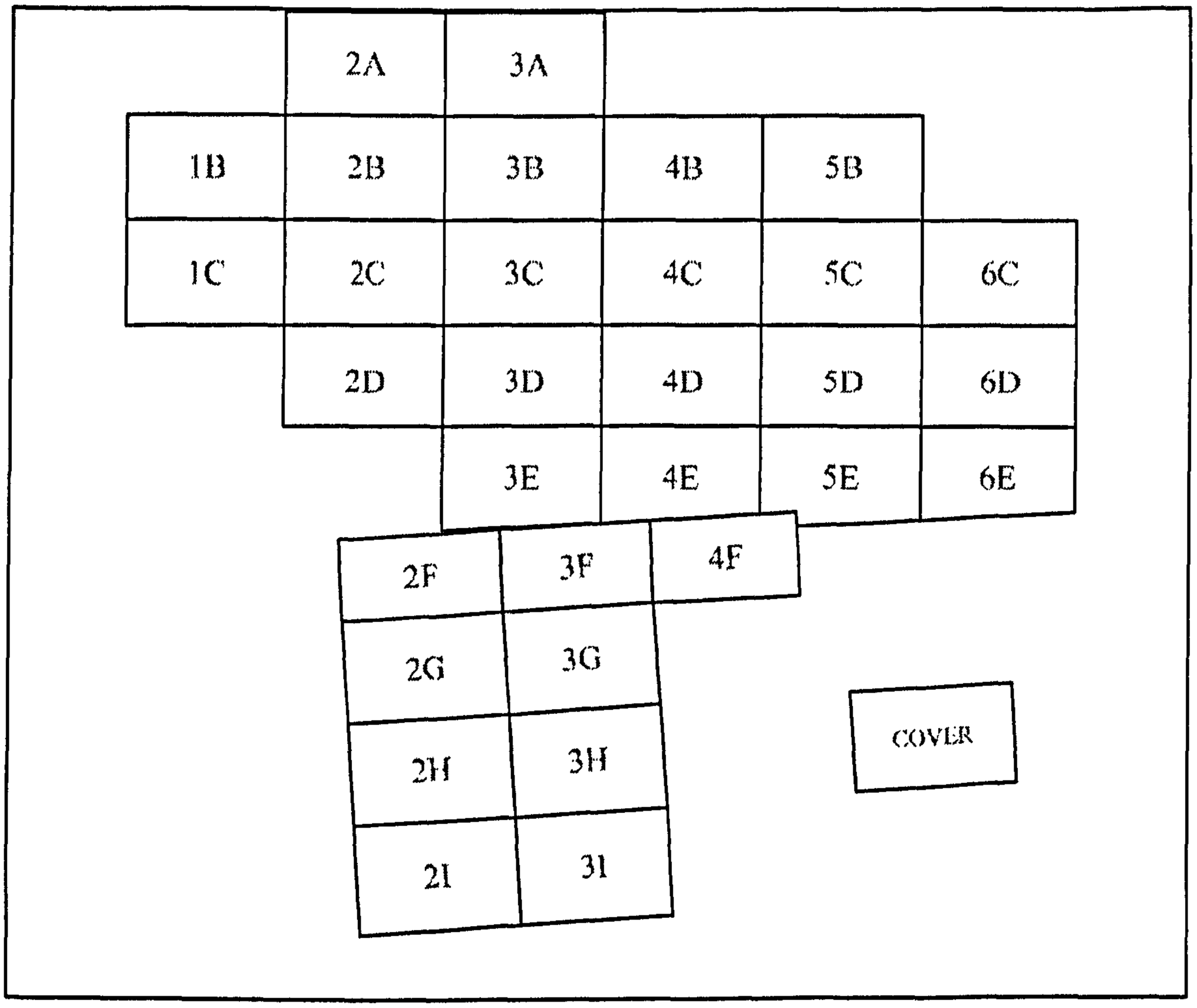



Figure 2.13 - Assigned Grid to the 1852 Board of Health Map

It will be noted that two separate grids are formed, namely;

- the main grid covering the original town and its then rural hinterland, all lying to the north of the Stockton to Darlington Railway Line. This group of plans comprised the bulk of the map twenty two (22 No) and are aligned generally north to south - although there is a slight variation which is discussed later, and
- a secondary grid comprising nine sheets lying to the south of the Stockton to Darlington Railway Line.

The map was expertly drawn, colour washed and contained a wealth of information, including;

- names of streets, yards and buildings, all labelled or numbered as appropriate,
- levels of property to various datum points,
- location and size of watercourses and ponds, and
- location of wells and pumps.

A manuscript note was added to the cover page:

'This plan corrected and additional sheets
with lines of pipes gas and water shown thereon up to March 10th 1870
by George Dickinson CE
Darlington'

It was taken that the additional sheets were those comprising the secondary grid, since the style is slightly different to the main grid and the offset nature of this.

When discovered the condition of individual sheets varied. The outer cover was very dirty and had suffered from the ravages of many years of handling. The 'town centre' sheets were also dirty, creased and worn badly in certain areas, clearly as a result of frequent referencing. Sheets covering the areas immediately outside of the densely populated urban area were in almost pristine condition. The maps were presented on heavy cartridge paper and mounted on linen sheets then bound on the left hand side by timber battens. Each map was hand drawn and colour washed to highlight the salient features depicted, ie buildings in red/brown; metalled areas in grey; grassland in green, with watercourses in blue. The characteristics of the 31 Maps as found are given at Appendix 21.

The first edition of the ordnance survey map was published in 1856 to a scale of 60 inches to 1 mile (1:1056) and comprised five streets measuring 3'0" x 2'0" (910mm x 610mm). Thereafter the Ordnance Survey were the principal mapmakers and have maintained a continuous cartographical record, updated at regular intervals to the present day. The 1856 First Edition Series could be considered to be a masterpiece of cartography. The map was very detailed, accurate and finely drawn and engraved onto copper plates depicting a wide range of physical features. Ironically, these maps were the most detailed ever produced by Ordnance Survey. In comparison, their modern day counterparts, produced with the benefit of advanced technology, are seriously lacking in this regard (Figure 2.14).

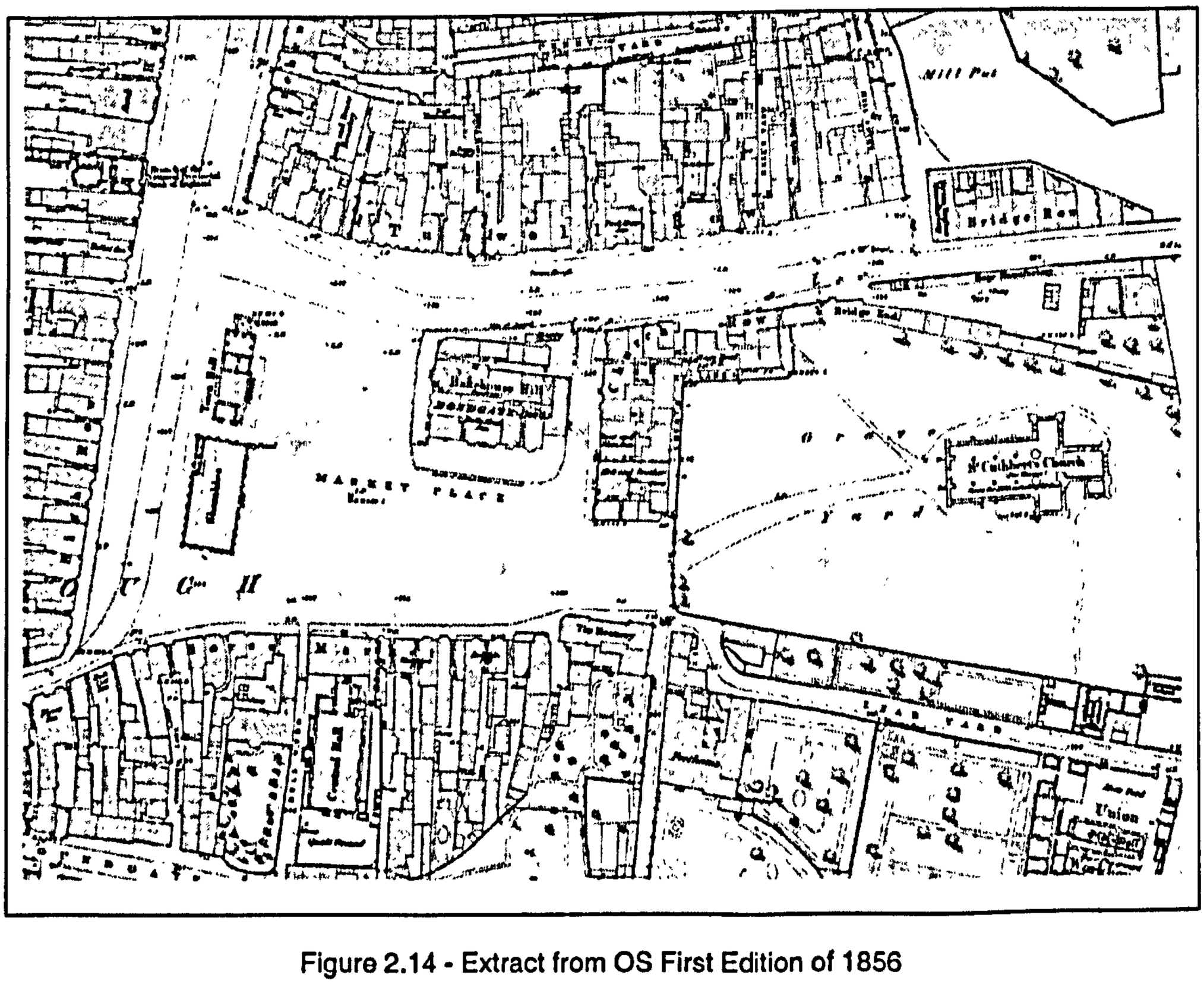



Figure 2.14 - Extract from OS First Edition of 1856

## 2.15. Standardisation of the Data

The plans and surveys of Mowbray 1776, Richardson 1788, Mowbray 1788 and 1789, and Pease 1792 were all reduced to the same scale, initially by hand, but later by computer scanning techniques. By the use of 'best fit' practices, the results were combined to produce a composite plan of the area spanning the 26 years between the plans and surveys. Although it was necessary to adjust boundaries, the surveys aligned extremely well. Perhaps the original works might have been an even closer fit, since only photocopies were available for analysis. A composite plan is shown in Figure 2.15.

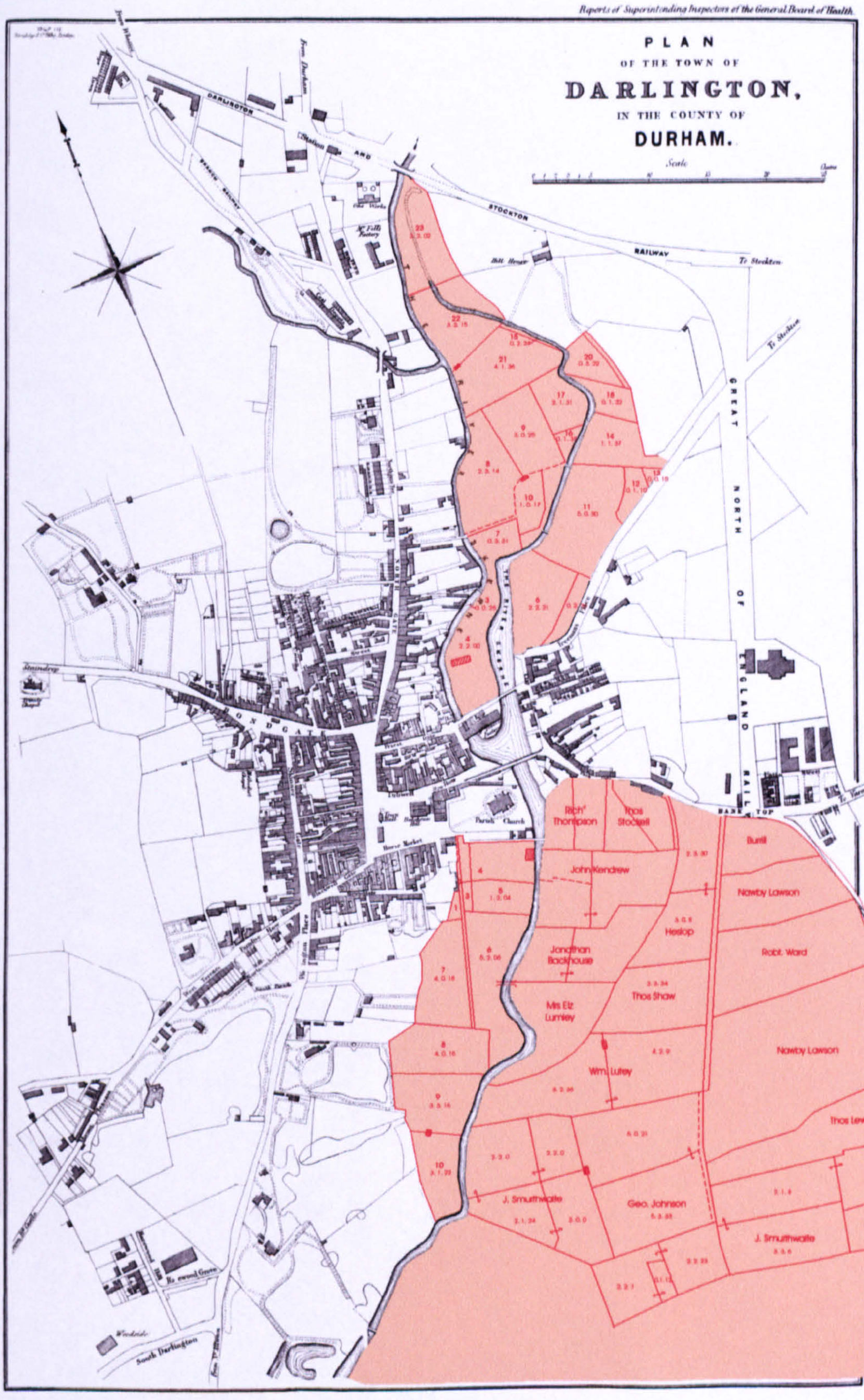



Figure 2.15 Composite Plan of Darlington derived from Plans & Surveys 1776-1792

No detailed plan was found for the area east of the River Skerne between Freemans Place and Clay Row, where a significant block of development was shown on the early published maps of the mid nineteenth century. Mowbray's plan of 1788 showed Low Parks in its environs to the north:

- The mill pond was in existence.
- Ribbon development on the eastern side of Clay Row.
- Only the Horse Mill buildings on the northern side of the Yarm Road.

It is therefore likely, that much of the area covered by Mowbray's 1788 plan was utilised by agriculture, as opposed to developed land as shown by later maps. Should this have been the case, then sometime prior to 1776 the established settlement of Darlington was wholly situated on the western slopes of the River Skerne.

The Woods and Reed maps, referenced Dmap $^{1826}$ and Dmap $^{1829}$ respectively were very similar in coverage and had been produced within three years of each other. Anthony Reed's map, however, was drawn to a larger scale, gave more detail and included a schedule of owners and tenants of property. It was decided, therefore, that the data in respect of Dmap $^{1829}$ would form the basis of investigation. Dmap $^{1826}$, however, was scanned in order to reproduce additional copies for future reference.

Dmap $^{1829}$ was initially photocopied, then digitised in several GIS data layers, namely;

- Roads,
- Buildings,
- Watercourses, and

- Names and Numbers.

This approach allowed for greater control and flexibility to be exercised over the outputs from the digitised computer model.

The schedule was found to be in poor condition, some sections had faded away, whilst some sections were missing completely; much, however, could be read or deciphered. The schedule contained unique primary evidence of the owners and tenants of property shown on the map. It was decided, therefore, to capture as much of the information as possible. The full analysis and rationale are given in the document 'Darlington Properties 1829' produced jointly by the writer and his colleague Kevin Dolan, together with voluntary help given by local historians. A typical page from the document is given at Appendix 22.

The degree of detailed information on Dmap [1852] was phenomenal and perceived to be potentially very important to many user groups ranging from civil engineers to social historians. As with Dmap [1829] it was decided to capture as much information as was practical and compile a single database (using Foxpro 2.5, Windows Version).

Much of the town layout appeared to be medieval in nature, centred around the Blackwellgate area. Numerous Yards were shown which may have arisen from successive divisions of the original burgage plots. Due to the potential importance of the Yards, which were assigned a unique code to denote their location and number, as illustrated by Table 2.18.

| Name of Street | Side of Street | Yard No | Yard Code |
|---|---|---|---|
| Blackwellgate | North | 2 | Blg N2 |
| High Row | West | 6 | Hir W6 |
| Post House Wynd | South | 4 | Pow S4 |
| Skinnergate | East | 14 | Skg E14 |

Table 2.18 - Examples of Yard Codes

Each Yard was coded in this manner. An extract of the original working papers showing the full coding for the Blackwellgate/Skinnergate/Post House Wynd/High Row block of properties is shown in Figure 2.16.

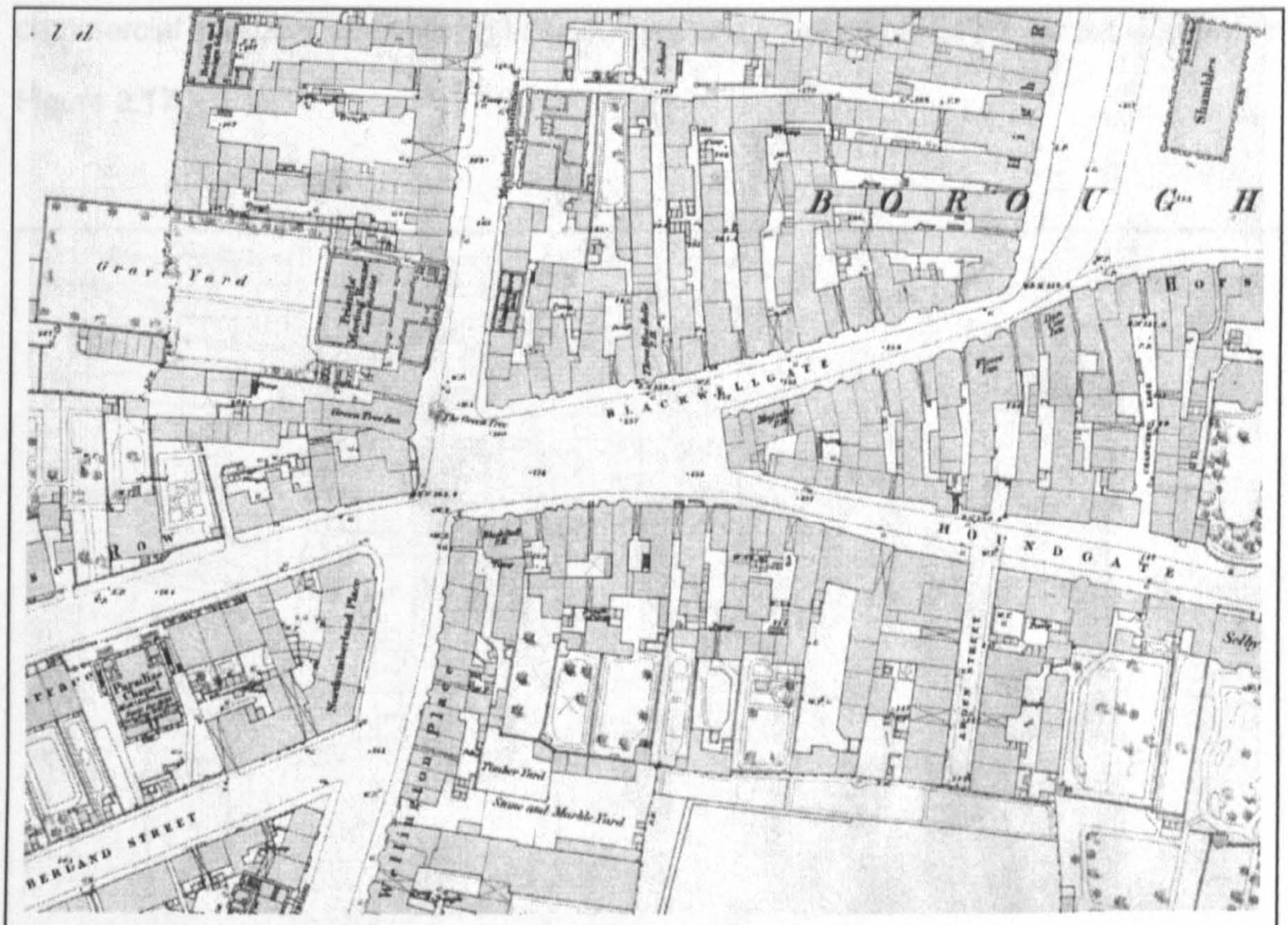



Figure 2.16 - The Yards around the Blackwellgate Area

The following information fields were established within the database to capture Dmap 1852 data as shown in Table 2.19.

| Names of Fields of Data | | |
|---|---|---|
| Sheet No | Property Number | Frontage |
| Street | Name Source | Area |
| Property (No/Name) | Street Code | Yard Name |
| Side of Street | Access | Yard Code |
| Level | Pumps | AP (Ash Pit) |

Table 2.19 - Data Fields used for Dmap [1852]

The full analysis and rationale is given in the document 'Darlington Properties 1852'.

Although the coverage of Dmap [1852] was relatively large, only the town centre area, comprising five sheets, was of particular concern. These sheets were digitised by a commercial company specialising in such work and an example of the output is shown in Figure 2.17.

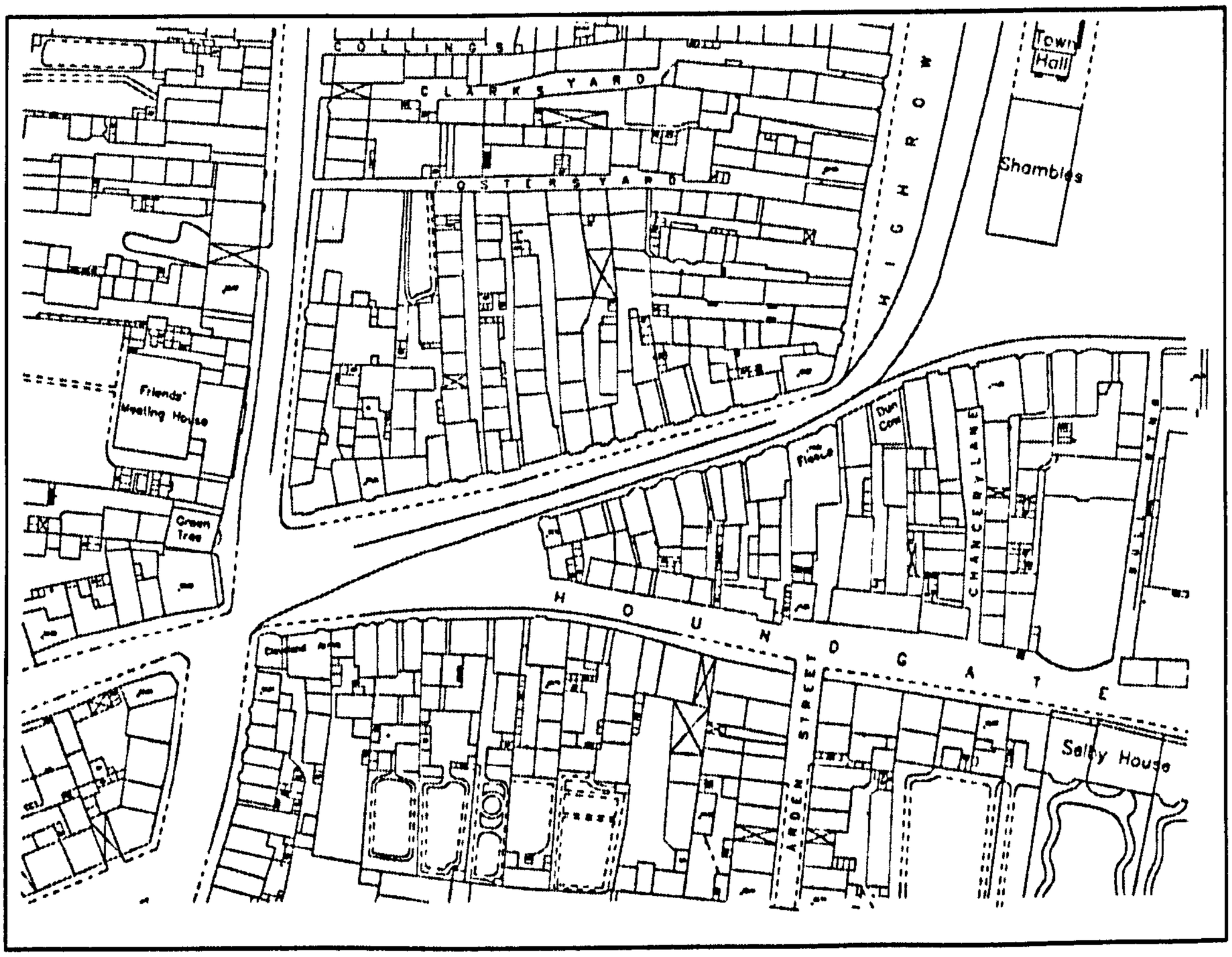



Figure 2.17 - Extract from Digitised Dmap [1852]

In order to maintain the maximum control and flexibility, multiple GIS layers were used.

The OS First Edition map, Dmap [1856] was also digitised by the same commercial company using multiple GIS layers.

Following devastating floods on the 14 November 1875, the town council commissioned J W E Harrison (a Westminster engineer), to design a suitable flood alleviation scheme to mitigate the effects of future events. Harrison produced four drawings of the river corridor

from the Stockton and Darlington Railway Bridge to the River Tees giving details of the then existing river and his proposals. The levels given by Harrison were relative to the Ordnance Datum.

## 2.16. Topography

The purpose of collecting topographical information was four-fold in order to determine;

- a ground model for the sub-region scoping area,
- a ground model for the town centre scoping area,
- the horizontal and vertical profiles of the Skerne Valley, and
- any changes to the river valley which may have altered the extent of the natural flood plain.

No comprehensive record existed to meet the above criteria, therefore it was necessary to construct models from historic data and establish the present day geometry of the river valley by conventional surveying techniques. It was not practical to attempt to survey the sub-region scoping area because of time constraints. Furthermore, the accuracy of the geological data is questionable in respect of the ground levels and would not match a precise ground level model.

The OS spot levels and the ground levels determined for the various boreholes were adopted as the main database for the sub-region scoping area. Caution was exercised, however, in respect of the accuracy that this approach achieved.

The ordnance survey maps show spot heights to one decimal place of a metre, ie ± 0.1m. These non-physical points have been determined by levelling. There is, however, an

issue with the degree of accuracy of this information. The OS Land-line User Guide illustrates and acknowledges the scale of the problem as shown in Table 2.20.

| Scale of Data | Achieved absolute accuracy | |
|---|---|---|
| | 63% confidence | 99% confidence |
| 1:1250 - urban | < 0.5m | < 1.0m |
| 1:1250 - rural resurveyed | < 1.1m | < 2.4m |
| 1:2500 - rural | < 2.8m | < 6.0m |
| 1:1000 - moorland | < 4.1m | < 8.8m |

Table 2.20 - OS Land-line accuracy achieved by various scale published maps

This levelling problem is greatest in the rural area, and stems from the old county series of mapping which was transferred onto the national grid by a manual overhaul procedure. Large errors as a result of human drafting have been discovered throughout the county and within the scoping area, particularly at the county boundary.

The earliest topographical information available for Darlington was found on Dmap [1852], an extract is given in Figure 2.18.

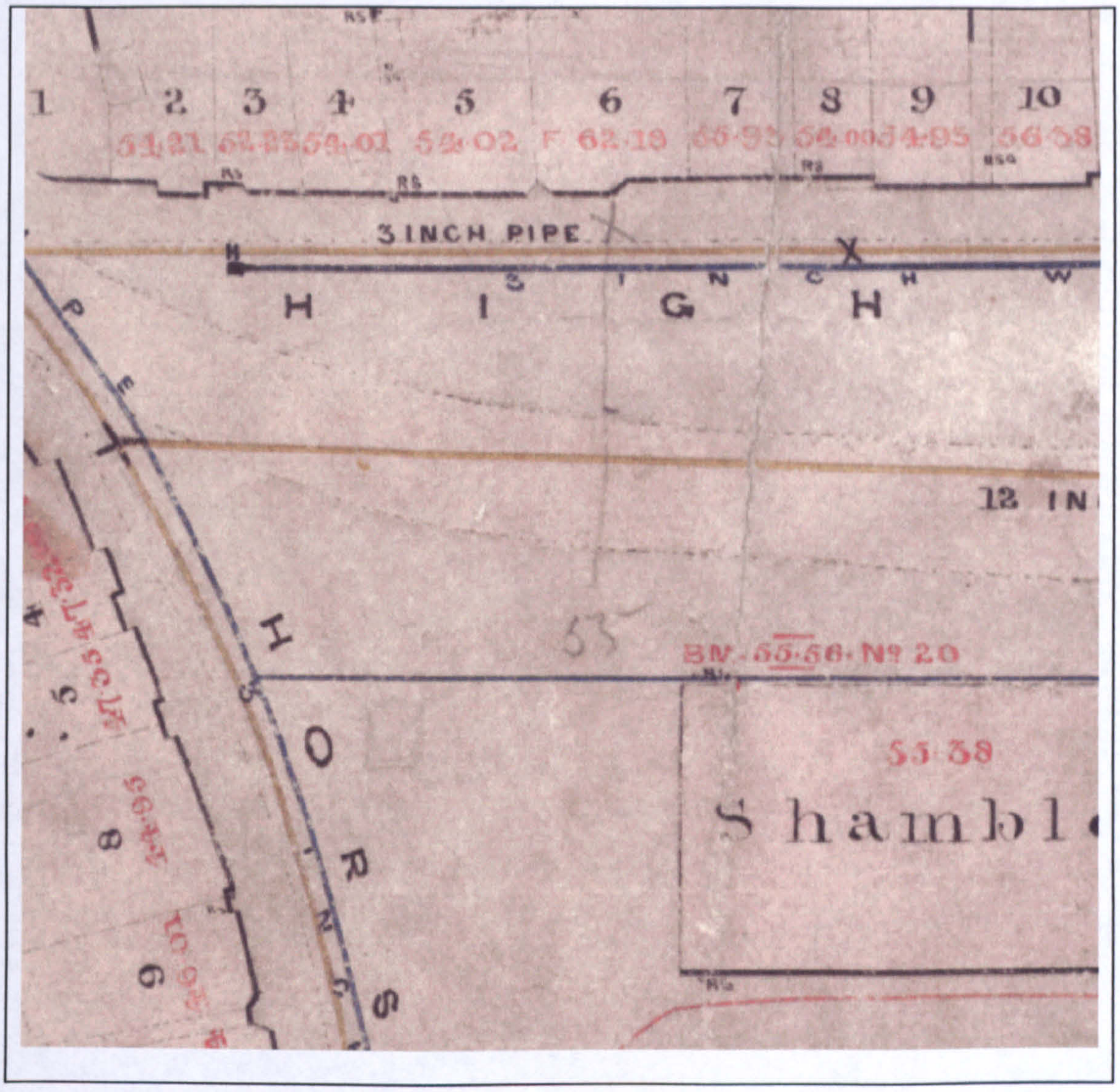



Figure 2.18 - Extract from Dmap [1852] Sheet C2

Generally, each property was numbered or named as appropriate and endorsed in red with a value given to two decimal places, ie 'The Shambles, 55.38'. These values have been taken to the floor levels of the property in feet. A series of benchmarks (BM) was also given - the one adjacent to The Shambles was BM 55.56 No 20. Other benchmarks were not allocated a number. It could not be determined from the map where the BM's were located. Furthermore, there were numerous BM's with different and apparently unrelated datums. It was possible, however, by a process of trial and error to establish that some of the adjacent values around the Deanery (off the Market Place) did correspond if a value of 20.00 was added to neighbouring values. This lack of definition appeared to be at odds with the general standard of accuracy and precision of the map.

Several buildings still exist and therefore some validation of the Dmap $^{1852}$ levels can be made.

Harrison's engineering drawings of 1876 some 24 years later showed a proposal for the horizontal and vertical alignment of the river. In some areas of the town centre the bed level was reduced by 1.5m (5 ft) and new cutting to a depth up to 3.0m (10 ft). All the levels were given in feet to Ordnance Datum.

The OS First Edition series, Dmap $^{1856}$ showed numerous spot levels. At this period the OS were using the Liverpool datum, therefore a slight adjustment was necessary to convert the values to Newlyn datum (ODN). The OS Durham Street Series (ie LV14) carries a footnote to the effect that levels were related to the Liverpool datum.

It can therefore be safely assumed that the levels given on the drawings related to the Liverpool Datum and not the Newlyn Datum - the reference used throughout this study.

Therefore converting to Newlyn datum (as used in this study):

Mean Sea Level at Liverpool = 0.650 feet below general Sea Level (Newlyn)

Hence

Level $_{1876}$ (m) = 0.3048 (Plan level + 0.650)

Consequently, all levels given on the Series 1876 have been converted to their metric equivalents. From the 1875/76 data a contoured map of the Town Centre area, Contours $^{1852}$ was drawn - Figure 5.1.

A series of OS plans dated 1947 with road construction levels given in feet to two decimal places and to OS datum was discovered in the Borough Engineer's Drawing Archive. Most of the town centre was covered. After conversion to metric equivalents the data were used to contour the area, the results of which (Contour $^{1947}$) are shown in Figure 5.2.

Having highlighted the inaccuracies of the OS spot levels, particularly at boundaries and rivers, methods of improving or checking the degree of accuracy were sought. Again, reference was made to the Borough Engineer's Drawing Archive and a large number of engineering drawings were examined for topographical information. Several hundred drawings had been produced for a variety of civil engineering projects. Invariably, topographical information was shown and nearly always with reference to OS Datum at Newlyn (OSN). An exercise was carried out to produce a composite plan with contours. It was observed that prior to 1970 little major work appeared to have been carried out, but after that date significant development had taken place. This arbitrary date was chosen as a basedate.

Using the data from the compilation plan of engineering projects, a composite contour map was drawn, referenced Contours $^{<1970}$ as shown in Figure 5.3.

The degree of fit at the project boundaries was excellent. Consequently this method of combining data proved to be satisfactory. This result was probably due to the quality of the original work, rather than the method. A similar exercise was carried out post 1970, again with good fit at project boundaries. The results, referenced Contour $^{>1970}$ are shown in Figure 5.4.

During the discovery process to establish the extent and frequency of flooding of the River Skerne, several engineering drawings were found in the Borough Engineer's Drawing Archive. The drawings were produced by the Wear and Tees River Board in 1952 and comprised longitudinal sections and cross sections from the River Tees to Aycliffe Bridge.

All relevant data were extracted from the drawings and committed to an Excel Spreadsheet, an extract of which is given in Appendix 23.

## 2.17. The River

The River Skerne, a tributary of the Tees, is a lowland river over its entire length (Archer, 1992). Darlington is the largest settlement within the catchment and straddles the river in its lower reaches (Figure 2.21). The town witnessed rapid industrial development in the nineteenth century, much of which was built on the active flood plain.

The River Skerne has had a frequent and natural tendency of encroachment onto the flood plain and in order to determine the extent of the flood plain it is necessary to compile a comprehensive record of the behavioural patterns of the river.

The Environment Agency (EA) has a statutory duty to record, maintain and publish information on flooding and indicative flood plains in respect of main rivers. Unfortunately, this public record source was found to be seriously lacking and therefore the definitive flood plain for a particular watercourse could not be established from the available data. Perhaps this situation is not that surprising, however, as the responsibility for main rivers and the associated hydrology has, in recent years, transferred a number of times from the public to private sector and back. It could be therefore suspected that with each merger/transfer there was a corresponding loss of primary documentation.

In the case of the River Skerne, and Darlington conurbation, the public record was such that it was considered so unreliable as to make informed judgements about the severe storm frequency and the location of the flood plain.

## 2.18. The Potential for Flooding

Flooding is a natural phenomenon and cannot ever be entirely prevented. Early river site settlers were aware of the risk of periodic flooding and mitigated against this by inhabiting higher ground, above the flood plain. It is suggested that most severe storms are frequent enough (perhaps two or three in a lifetime) to be remembered and even the more catastrophic storms may have become enshrined in the folk memory and the information passed verbally from one generation to another.

With the passage of time, many riverside settlements tended to expand onto the flood plain, the perceived risk of flooding having been outweighed by social and economic considerations. These developments often also altered the original flood plains and tended to mask the tell-tail demarcation limits.

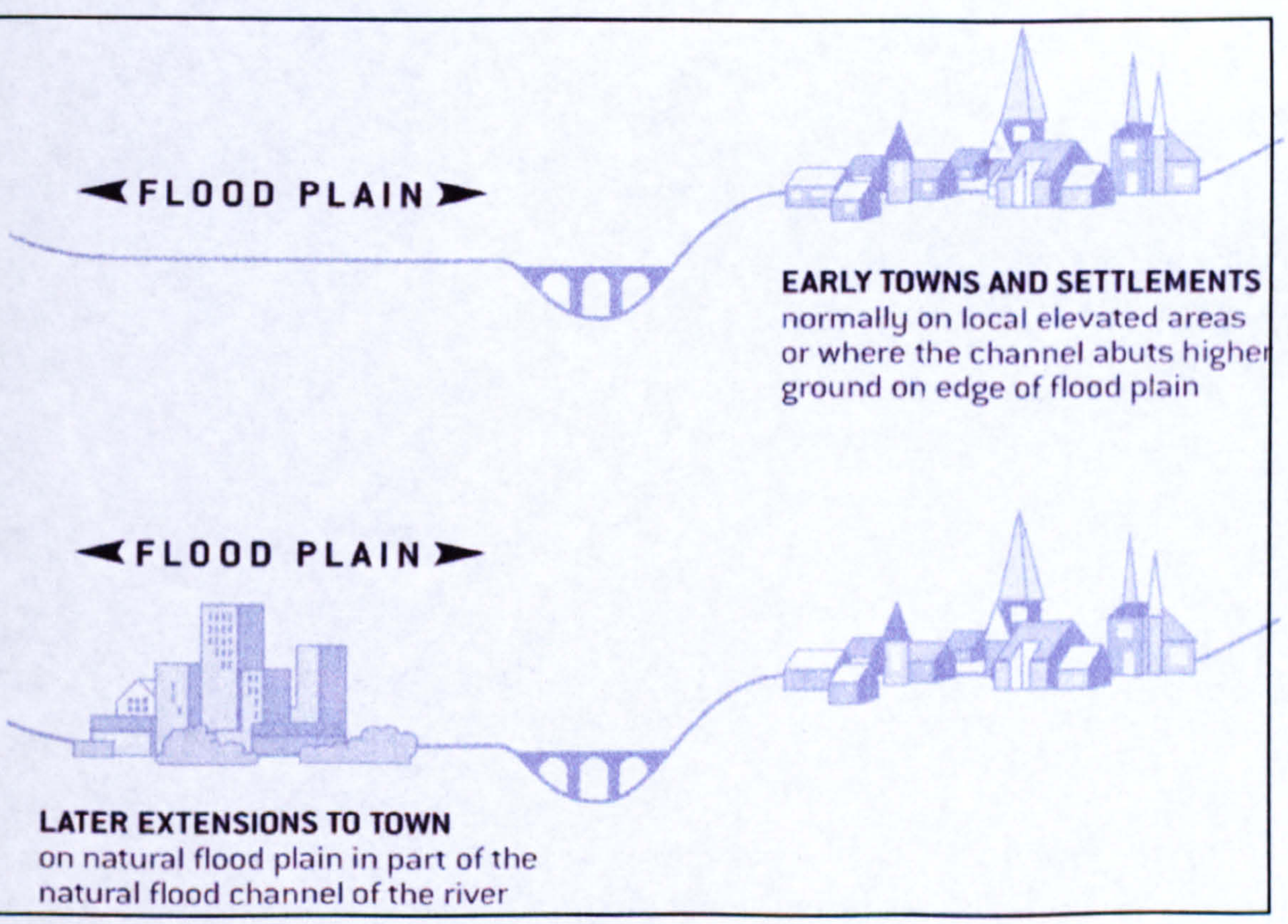



Figure 2.19 - Sequenced Development by Rivers (modified from ICE 2002)

The flooding characteristics and behaviour of the River Skerne, in relation to Darlington were investigated in the present study once the extent of the flood plain had been

established, in conjunction with the frequency of severe storms. The study suggested that considered judgement could be made on a number of important issues, including the;

- outer limits of any early towns and settlements,
- vulnerability of flood plain developments,
- appropriate flood defence strategies to mitigate the adverse effects of flooding, and
- ability to make rational decisions based upon cost benefit analysis techniques.

## 2.19. The River Network

The River Skerne originates north west of Trimdon Village National Grid Reference (NZ 4370 5340) and joins the River Tees near the Village of Croft at (NZ 4289 5101), a total river length of about 50 km. The configuration of the rivers and their catchments is given in Figure 2.20.

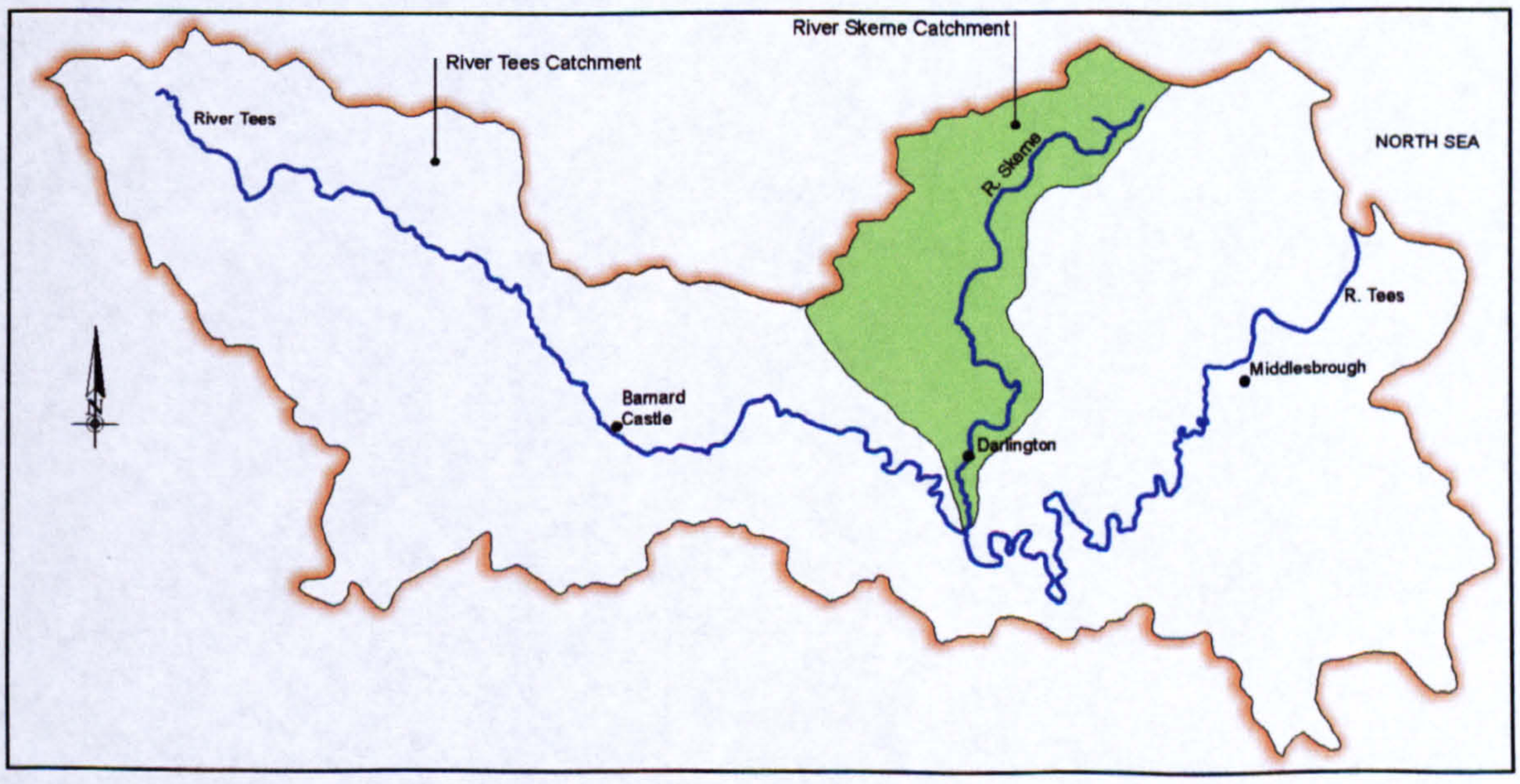



Figure 2.20 - River Tees & Skerne Catchment Areas

The EA estimate that the Tees Catchment drains approximately 1,930 $km^2$ from its source in the Pennines to its mouth at the Tees Estuary.

The River Skerne catchment area is given in Appendix 24 and is based on the plan prepared by the Borough Surveyor to Darlington Borough Council in 1946. The extent of the catchment is given as 255 $km^2$ (98.8 square miles).

### 2.19.1. Natural Tributaries

Throughout the length of the River Skerne there are a number of natural tributaries, all of which contribute to the hydrological profile of the main river (Figure 2.21).

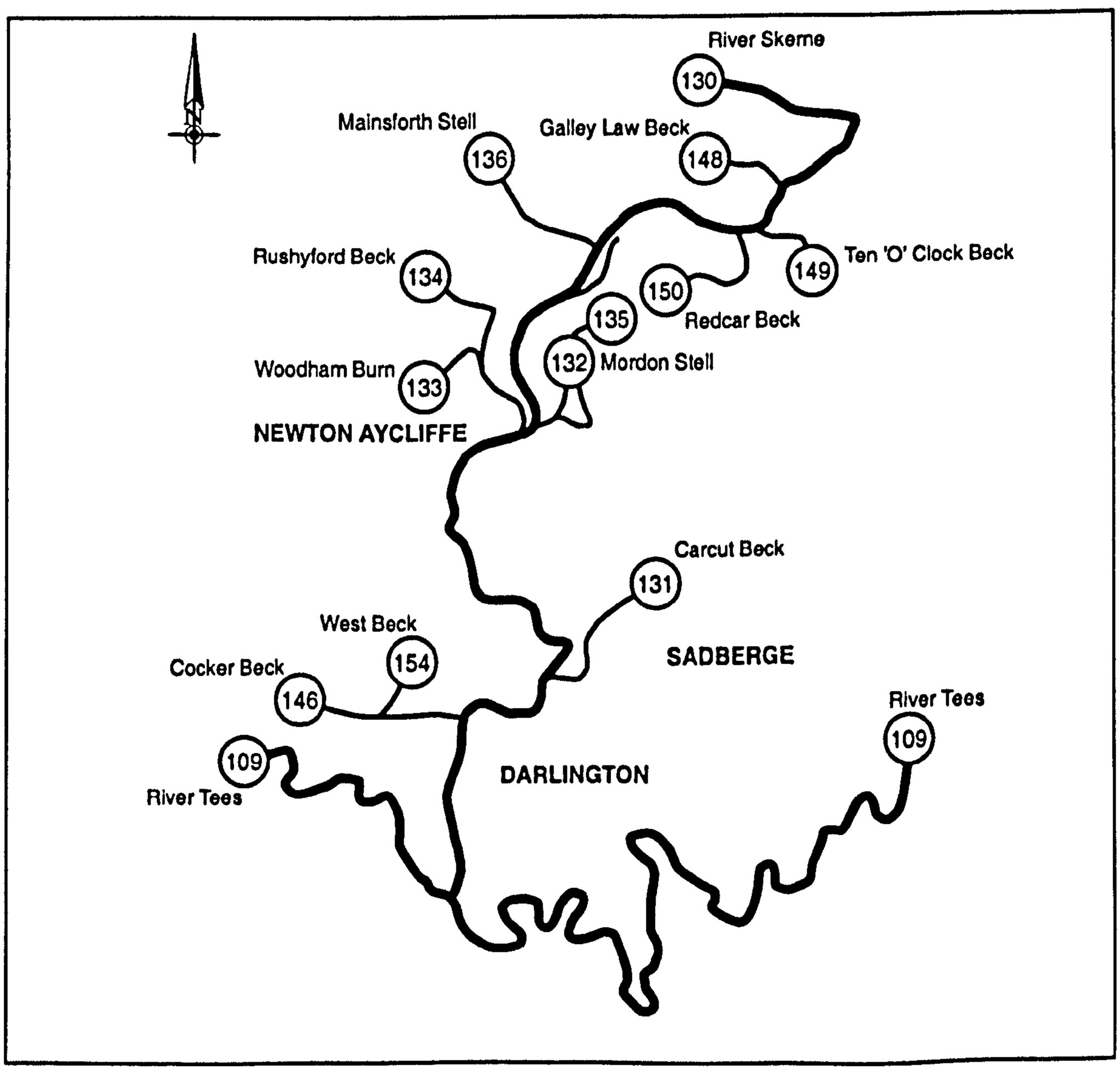



Figure 2.21 - River Skerne : Natural Tributaries (based upon data from the EA, 2000)

### 2.19.2. Major Surface Water Sewer Outlets

As the Darlington urban development has proceeded, a number of large surface water sewer (SWS) outlets have been constructed to the River Skerne to drain the associated settlements (Figure 2.22).

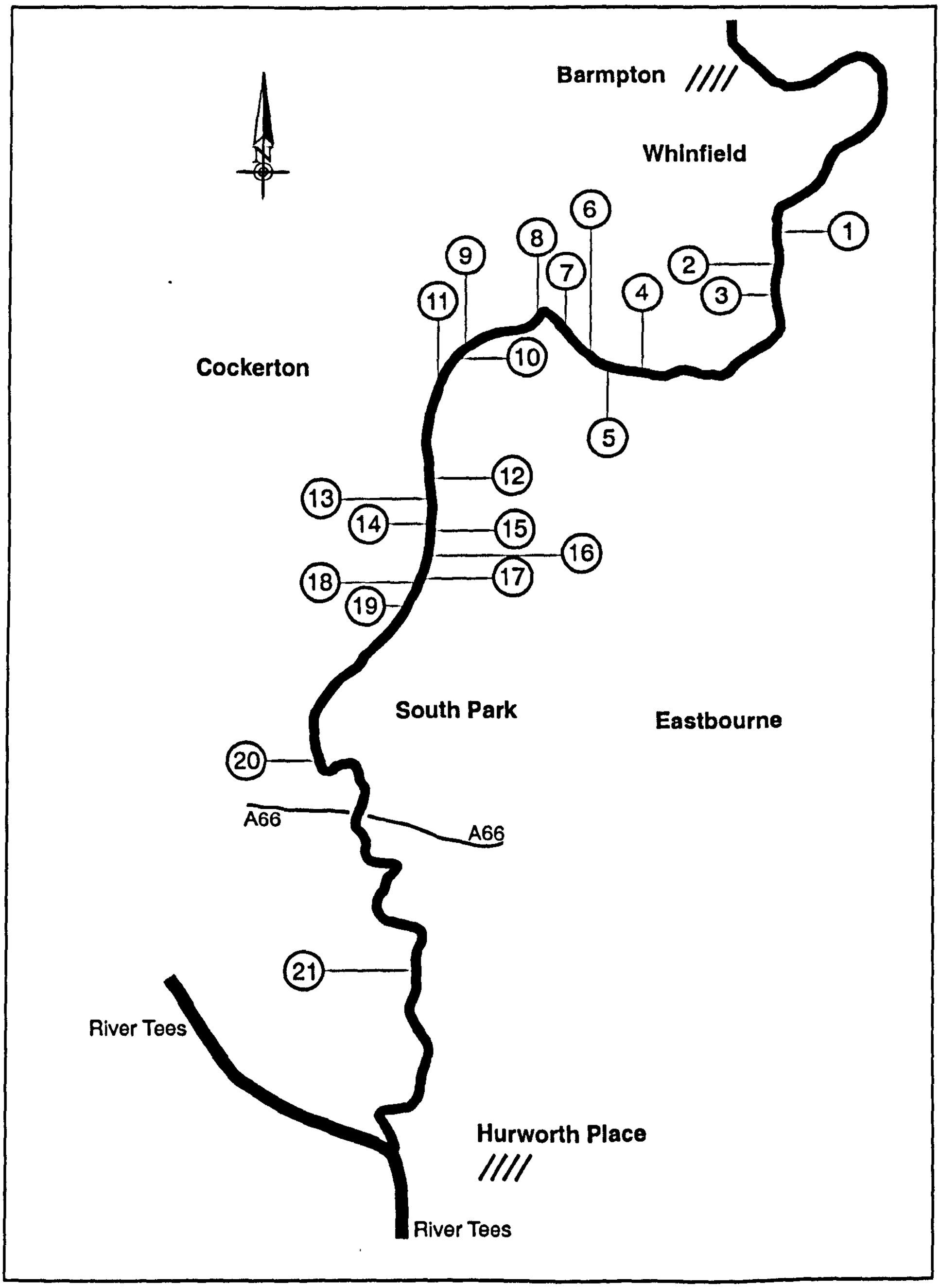



Figure 2.22 - River Skerne SWS Outlets, Darlington principal outlets in excess of 450 mm diameter.

The surface water sewer outlets, in excess of 450mm, discharging to the Skerne between Stockton Road (Figure 2.20), and the confluence with the Tees are indicated in Table 2.21. Some of the surface water sewers may have replaced original natural watercourses.

| No | Name | Dia mm | Grid Reference |
|---|---|---|---|
| 1 | Barmpton Lane Sewers | 850 | 431650 516798 |
| 2 | Whinfield Road Sewers Gt Burdon Outfall | 2100 | 431661 516496 |
| 3 | Whinfield Road (see also Plan 3112/1) | 750 | 431625 516422 |
| 4 | Salters Lane South | 600 | 430717 515766 |
| 5 | Red Hall & Haughton Road & Hundens Lane | 900 | 430505 515780 |
| 6 | Hutton Avenue | 450 | 430200 516020 |
| 7 | Riverside Way Extension | 525 | 430172 516048 |
| 8 | Springfield Road | 900 | 430053 516204 |
| 9 | North Ward Sewers (Askrigg Street) | 1300 | 429539 516054 |
| 9 | North Ward Sewers (Askrigg Street) | 1100 | 429539 516054 |
| 10 | Cleveland Industrial Estate (The Forge) | 750 | 429380 515890 |
| 11 | Whessoe Road Sewers | 675 | 429228 515720 |
| 12 | Eastmount Water Course (Valley Street) | 900 | 429286 514828 |
| 13 | St Cuthbert's Way IRR 3A Russell Street | 675 | 429166 514768 |
| 14 | East Street | 600 | 429148 514679 |
| 15 | Brunswick Street | 600 | 429155 514594 |
| 16 | Parkgate Surface Water Sewer | 675 | 429168 514465 |
| 17 | St Cuthbert's Way Police Station Area | 450 | 429162 514348 |
| 18 | Town Hall Area Outfall 'A' | 600 | 429132 514295 |
| 19 | Victoria Road Sewers | 450 | 429020 514063 |
| 20 | Main Outfall Sewer Overflow @ SP/Park | 1220x1070 | 428395 512933 |
| 21 | Sewage Works Outfalls (3 No) | 900<br>600<br>450 | 428812 510336<br>428810 510330<br>428890 510196 |

Table 2.21 - Named SWS Outlets to River Skerne

## 2.20. Run-off

Run-off in all river catchment areas is influenced by land use, topography and underlying geology. In the upper reaches of the River Tees, the land use comprises moorland and rough pasture, which gives way to more intensive agriculture and mixed land use in the middle reaches. In the lower reaches the catchment includes much urbanisation together with significant industrial activity. The watercourses within the catchment are generally very steep, especially in the Pennine uplands.

The River Tees originates at Teeshead on the eastern slopes of Cross Fell in the northern Pennines (NY 700341), close to the watershed with the South Tyne River. Although the Tees then flows over Palaeozoic strata (Ordovician to Permian age) from its source to Darlington, the nature of the river is largely determined by the more recent superficial deposits which mask the solid geology.

In the upper reaches of the Tees valley the solid geology is largely represented by Lower Carboniferous cyclic deltaic sequences comprising marine limestones with associated deltaic sandstone and shales. However, in the Cauldron Snout to Low Force areas (NY 814287 to NY 903281), the river runs over doleritic bedrock (the Whin Sill), and also the faulted Ordovician basement rocks of the Teesdale inlier at Cronkley Pastures (NY 846296).

In the upper catchment area of the River Tees, the landscape is masked by Quaternary boulder clay deposits, and considerable thicknesses of Holocene peat, the latter resulting in the characteristic brown colouration (due to humic acids) to the water of the River Tees.

In the wider middle and lower valley sections of the River Tees, the river passes over fluvio-glacial sands and gravels which were deposited in the late Quaternary by the

retreating ice sheets. These stratified clastic deposits are sporadically supplemented by lowland peat deposits, especially in the area around Darlington.

The River Skerne issues on the Permian limestone country 0.5 km north west of Trimdon Village, County Durham (NZ 362 349), in a valley system developed along the important Lunedale-Butterknowle Fault system. This east-west fault system delineates the boundary between the southern margin of the Caledonian Alston Block and northern edge of the Tees Basin - Stainmore Trough.

The Skerne Valley seen north of Trimdon Village is far too large for the present stream and it is possible that this valley formed part of a much larger pre-Devensian river system, part of the pattern of east directed 'Denes' so much a part of the East Durham landscape (Smith *et al*, 1976).

However, much of the Permo-Triassic bedrock which underlies the present meandering course of the River Skerne is masked by deposits left by the passage of the Devensian ice sheets (tills, lacustrine clay) and also during the retreat of the same ice sheets (outwash sands and gravels with subordinate deposits of peat).

The complete infill of the large pre-Devensian fault controlled Skerne valley by boulder clays to the east of the Hurworth Burn Reservoir (NZ 410 340) has effectively caused the present River Skerne to flow southwards into the Tees Basin down the Permian limestone dipslope.

The extremely undulating nature of the landscape in the catchment area of the River Skerne is caused by glacially related superficial deposits, for example the drumlin fields east of Sedgefield (NZ 385 288), which has resulted in the meandering nature of the current River Skerne valley (Figure 2.22).

On site there is much evidence of a wide flood plain with many meanders and former ox-bow lakes visible over much of its length. By contrast, the river course is channelised within the urban settlement of Darlington. With the exception of the Darlington conurbation area, the river almost entirely traverses mixed agricultural land. The watercourses within the catchment have generally moderately steep slopes.

## 2.21. Principal Discharges

Throughout the length of the River Skerne, there are numerous discharges contributing to the total flow, these include;

- direct run-off,
- natural watercourses,
- the surface water drainage system, and
- land drainage.

Many of these discharges are not directly measurable.

## 2.22. The Recorded Floods

A uniform approach to the extraction of evidence has been adopted when recording the individual flooding events. Information has been captured from four different sources:

- Newspaper Articles

  Each report discovered has been reproduced in the Appendix 25. Relevant extracts from the report have been quoted in the text relating to the

appropriate flood (Sources: The Northern Echo, The Darlington and Stockton Times and the Durham Advertiser).

- Engineering Information

Where civil engineering information has been discovered, the document has been included in Appendix 26 as a permanent record. Relevant extracts from the drawings, such as flood levels and chainages, have been presented in tabulation form within the text.

- Formal Minutes of Statutory Bodies

If a reference to a particular flood is recorded in the Darlington Borough Council Minute Book, a relevant extract to a particular flood is included within the text. Where no reference is available, mention is also made to that effect. The Wear and Tees River Board published Annual Reports between 1952 and 1965 and the Morden Carrs Drainage Board Minutes are referred to as appropriate. A limited number of references have been taken from published documents.

- General

No records of flooding on the River Skerne were discovered prior to 1850. Archer (1992) concluded that *any flooding which did occur only affected wet pastures on the flood plain and hardly excited comment*.

## 2.23. The Flood [1771]

The Great Flood of 1771 is generally poorly recorded; however, there are many passing references to its effect within the northern region. Extracts from Graham (1975) are reproduced in Appendix 27.

No direct reference to the effect of the great flood of 1771 on the River Skerne is made by Graham in respect of the damage to bridges; he nevertheless refers to the effect of this flood on Darlington Bridge. In respect of the River Tees, evidence of the 1771 flood can be found at Yarm as the maximum flood level was recorded on a plaque built into the eastern gable of the Old Town Hall (NZ 441909 512841). Furthermore, the maximum flood level of a second flood in 1881 is also recorded in a similar manner.

Figure 2.23 - Record of the 1771 & 1881 Flood at Yarm, Cleveland)

The plaque recording the highest flood level on 17 September 1771 is located just below the keystone in the brick arch above the open door. The plaque recording the flood of 10 March 1881 is located in the pillar between the two brick arches. The distance between the two floods is 1.67m. The actual flood levels relative to ordnance survey datum are:

- 17 September 1771 9.30m AOD
- 10 March 1881 7.63m AOD

It is not known what effect, if any, the Flood [1771] had on the River Skerne. However, the evidence from the devastation caused to the region's bridges on the Rivers Tyne, Wear and Tees suggests that the catastrophic storm was widespread. Consequently, it seems most unlikely that the catchment of the River Skerne would have escaped its effects.

No drawings showing the impact of this flood, if any, were discovered during the study.

## 2.24. Flood [1852]

The first recorded flood reported in a newspaper was that of 29 September 1852. The Durham Advertiser reported:

> *North of Darlington a mile or two the line begins to traverse a dead level and for some miles the water was found standing for more than 100 yards on each side of the line, which passes across the plain on a slightly raised embankment. Bye and bye the rails became altogether submerged and the engine with its heavy toll of carriages slowly proceeded to clear the way through the immense lake one to two feet in depth. A brilliant moon shining through a clear frosty sky lighted up the inland sea, the train was thus strangely navigating and showed the water flashing through the wheels of the carriages as through the paddles of so many little land steamers. Only by the top of the hedgerows and trees arising out of the water could the passengers be convinced that the train was actually traversing an inland country and not an arm of the sea.*

No reference is made to the town of Darlington, although it is known from historic maps that the low-lying areas adjacent to the River Skerne, such as Clay Row, Church Row etc were developed and within the natural flood plain.

## 2.25. Flood [1856]

Four years later, on 29 September 1856 it was reported by the Northern Echo that several hundred acres of land between Ferryhill and Aycliffe were flooded and that the water reached over the footboards of the rail carriages.

## 2.26. Flood [1875(1)]

The River Skerne catchment was subject to heavy rain on the 19 and 20 October 1875 and the effects of the incident were reported on Friday, 22 October 1875 in the Northern Echo under the *Great Flood of Darlington* (Appendix 25). It was reported that the flood was the *most serious flood that had occurred within at least an half a century.* Apparently rain had fallen incessantly for two days on the Tuesday and Wednesday and some accurate observations of rainfall had been made by Backhouse, as recorded in the article as follows:

| | | |
|---|---|---|
| *From 8am on the 19th to 8 am on the 20th as* | *0-75/100 inch* | *(19mm)* |
| *From 8am on the 20th to 8 am on the 21st as* | *1-61/100 inch* | *(41mm)* |
| *Total rainfall in the 48 hours was* | *2-36/100 inch* | *(60mm)* |

According to Backhouse the rainfall for the 48 hour period was therefore 2.36 inches.

The Northern Echo article (Appendix 25) states that a great quantity of rain fell in the district around Darlington and *in consequence of which the tributaries to the River Skerne began to pour in large quantities of water.* Reference was made to both Morden Carrs (NZ 4325 5259) and Aycliffe (NZ 4285 5225), the former being located towards the upper reaches of the River Skerne catchment area and the latter in the middle catchment. According to Archer (1992), further reference was made in the Minutes of the Morden Carrs Drainage Board that:

> *... several farm bridges were washed away, including the Middleham bridge, Island Farm bridges, Low Copelaw bridge and the Fourmart's bridge near Mainsforth.*

Consequently, it would appear reasonable to assume that the majority of the catchment area was subject to a rainfall of about 2.36 inches (60mm) for the 48 hour period between the 19 to 20 October 1856.

The Northern Echo article charts the progress of the flood location by location and the relevant extracts are reproduced in Appendix 25.

## 2.27. Flood [1875 (2)]

Three weeks after the reporting of the *'Great Flood at Darlington'* the Northern Echo further reported on an even worse flood documented in the following articles:

| | | |
|---|---|---|
| 15 November 1875 | - | Darlington Flooded Again |
| 15 November 1875 | - | Great Floods in the North |
| 16 November 1875- | - | The North-Eastern Main Line Damaged |
| 17 November 1875 | - | The Late Flood in Darlington |
| 18 November 1875 | - | Darlington - Distribution of Coals |

Copies of appropriate extracts from the articles are given in Appendix 25. The format of the data as presented appears odd today and some analysis is needed to check its validity against that provided by Mr A Atkinson of the Meteorological Station.

If we assume the following:

| | | |
|---|---|---|
| Rainfall for 24 hrs up to Sunday (8 am) as | $2\text{-}^{3}/_{100}$ inch | (52 mm) |
| Rainfall for 24 hrs up to Monday ( 8 am) as | $0\text{-}^{75}/_{100}$ inch | (19 mm) |
| Then total rainfall for the 48 hr period was | $2\text{-}^{78}/_{100}$ inch | (71 mm) |
| | = 2.78 inches | (71 mm) |

Turning to the quantity of water discharged during the 48 hour period as 275 Ton/acre, the following calculation gives a corresponding rainfall value.

Assume 1 $ft^3$ = 62.5 lbf

Then,

Volume of Water = $\frac{275 \times 2240}{62.5}$ $ft^3$

= $\frac{9856}{}$ $ft^3$

Rainfall = $\frac{9856 \times 12}{4840 \times 9 \times 9}$ in

Rainfall = 2.72 inches (69 mm)

Comparing the Atkinson and Backhouse values for rainfall and cross-referencing these against the total discharge of 275 Ton/acre, we have three values of 2.71 in; 2.78 in and 2.72 in.

These values have a mean of 2.74 inches with a standard deviation of $3.8 \times 10^{-2}$ Consequently, there is an excellent match between these values. Furthermore, a rainfall figure of 2.74 inches appears to be totally reasonable in practical terms and is of the magnitude expected to cause widespread flooding of the district.

The Northern Echo, 18 November 1875 reported:

> ***The Recent Floods Darlington - Distribution of Coals***
>
> *As there were from seven hundred and fifty to eight hundred houses invaded by the Skerne, inhabited by more than 3,000 individuals ...*
>
> *Before the distribution commenced, Mr Hudson Reah, the surveyor, together with his staff, made a thorough survey of the whole area covered by the flood, and coals either have been or will be led to every house within the limits marked out on that survey.*

The storm of 14 November 1875 is also recorded in FORDYCE (1857) - Local Records held in the Public Library in Crown Street, Darlington under references U405A. Whilst

much of the report is identical to the Northern Echo reports, some supplementary information is given:

> *In the afternoon bread and coffee were supplied in the Lecture Room to nearly five hundred men, women, and children who were excluded from their own homes ...*
>
> *Others, again, were furnished with beds at the Workhouse; while others, who steadily refused Workhouse fare and quarter, preferred to sit up throughout the whole of the night in the rooms placed at their disposal in the Central Hall.*
>
> *The flood had completely submerged the whole of the works, drowning out all the fires, and almost completely filling the retorts.*
>
> *... as in the case of Backhouse Street and Skerne Row, which were not really passable until a later hour; nor was it until the afternoon that the fields near the Skerne, including the cricket field, Feethams, and Polain Bottoms, began to show visible signs of the flood abating.*
>
> *The woollen mills of Messrs. H. Pease and Co. were unable to make a start, owing to the drowning out of the boiler fires; and the Bridge Street Board Schools could not be opened because the water in that thoroughfare had not sufficiently abated.*

The additional evidence provided by Fordyce can be summarised in Table 2.22.

| Status | Location |
|---|---|
| Above flood plain | • The Lecture Room<br>• The Workhouse ❶ |
| Flooded Area | • The whole of the Gas Works.<br>• The Cricket Field.<br>• Feethams.<br>• Polam Bottom.<br>• Pease's Woollen Mill |

Table 2.22 - Fordyce : Additional Evidence

❶ There appears to be a conflict in that the Workhouse is within the suggested flood plain. It is opposite the Grammar School and immediately adjacent to the River.

Furthermore, the article states that Feethams was flooded, which appears to be higher ground than that of the Workhouse.

Reference to Dmap [1852], Sheet D3 which shows the area in Figure 2.24.

Figure 2.24 - Dmap [1852] Workhouse Area

Dmap [1852] gives the relative floor levels of the Workhouse and nearby properties, as shown in Table 2.25.

| Property | Floor Level (ft) |
|---|---|
| Workhouse | 24.58 |
| Grammar School | 27.72 & 25.62 |
| St Cuthbert's Church | 30.64 |
| Skerne Row | 22.73 to 23.39 |

Table 2.25 - Workhouse Area - Floor Levels

From this evidence, the Workhouse must have flooded. Was it that the conditions of the Workhouse - perhaps a two-storey building, were not too demanding? Certainly, it appears to be logical to include the Workhouse in the flood plain.

When comparison is made between the rainfall figures provided by Backhouse and Atkinson (1875) for the October and November storms respectively, the values are similar (2.71 v 2.78). The effect of the November flood, however, was much greater than that of October since the rain fell on an already saturated catchment.

As a consequence of the severe flood arising from the storm on 14 November 1875, the Council commissioned JWE Harrison to design a flood defence scheme to prevent such flooding for the future. Harrison worked in collaboration with the Council's Engineer, Mr. Reah and reported to the Council on 9 March 1876.

Harrison's work provided the first cartographical evidence of the River Skerne related to Ordnance Datum.

The record took the form of a set of four engineering drawings, detailing the physical characteristics of the River Skerne from the Stockton & Darlington Railway Bridge to Oxneyfield Bridge, the 'town centre' lying approximately mid-way between these locations. The drawings were discovered in a very poor condition within the Borough Engineer's Drawing Library at the Town Hall in Darlington. These drawings, like many others, were

not catalogued but bore reference numbers (Nos 402, 403 and 404) itemised in Appendices 26 & 28.

Although in a distressed condition, these hand-drawn original drawings in indian ink with a watercolour wash applied to a heavy linen cloth, incorporating a multi-layered paper drawing surface, were still in a readable condition with a surface loss of detail estimated at less than 0.5%. Of the four drawings in the series, three are titled *'River Skerne Improvement'* with the fourth titled *'Skerne Flooding'*. Each drawing is endorsed in handwriting *'1 Westminster Chambers, March 9th'1876* and signed *'J.W.E. Harrison'*. The sections given on drawing Nos 1 and 4 were related to Ordnance Datum (Liverpool). It can therefore be safely assumed that the levels given on the drawings related to the Liverpool Datum and not the Newlyn Datum - the reference used throughout this study.

Therefore converting to Newlyn Datum (as used in this study):

Mean Sea Level at Liverpool = 0.650 feet below general Sea Level (Newlyn)

Hence

Level $_{1876}$ (m) = 0.3048 (Plan level + 0.650)

Consequently, all levels given on the Series 1876 have been converted to their metric equivalents and the maximum flood level attained at various strategic locations tabulated (Table 2.24).

| Station | Recorded Flood Levels | |
|---|---|---|
| | ft | m |
| Victoria Road Bridge | 122.69 | 37.40 |
| Leadyard Bridge | 125.39 | 38.22 |
| St Cuthbert's Bridge | 125.59 | 38.28 |
| Priestgate Bridge | 126.12 | 38.44 |
| East Street Bridge | 127.00 | 38.71 |
| Russell Street Bridge | 131.00 | 39.93 |
| John Street Bridge | 135.80 | 41.39 |
| Main Line Railway Bridge - downstream | 136.50 | 41.61 |

Table 2.24 - River Skerne : Flood Levels 14 November 1875

The data recorded on the four drawings can be then related to Flood [1875].

No Council Minutes are available for this period.

## 2.28. Flood [1876]

The Northern Echo reported on the 22 December 1876 the effects that several days of heavy rainfall had on the town. Whilst no houses were flooded the article stated:

> *... Yesterday morning, it (the flood) began to force the water up the drains in Clay-row, and broke over Peaceful-valley.*
>
> *... the water with difficulty got under the Lead-yard Bridge. The end of Church-street and others in that quarter were flooded to a depth of several inches. Between eight and nine o'clock the river attained a greater height and broke over Clay-row at the ford near the Stone Bridge. Further up the row the water rose through the sewers till it stood to a depth of four or five feet at the bottom of Priestgate and Haughton-lane.*

No other records were discovered in respect of Flood [1876].

## 2.29. Flood [1880]

The Northern Echo, dated 29 October 1880 reported on the flood occurring on 28 October 1880, Flood [1880]. The article made reference to the fact that Darlington, as usual, had been considerably affected by the floods resulting from heavy rain, despite the precautions adopted some time ago. A clear reference to the fact that Harrisons solutions had not been totally successful. The river overflowed its banks at Albert Hill and at Parkgate. Elsewhere the water was flowing down the streets. The extent of flooding was identified as:

- The gasworks were partially flooded.
- The low lying parts of the town being generally flooded.

The article further states that the quantity of rain registered in Darlington at 9 am on 28 October 1880 for the previous twenty four hours was 1.89 inches (48mm).

No Council Minutes are available for this period.

## 2.30. Flood [1881]

The Northern Echo dated Thursday 10 March 1881 reported on the Great Floods on the Tees, Wear and Derwent. The headlines were designed to be eye catching:

*Bridge Swept away at Barnard Castle*

---

*Two men drowned*

---

*Malton Bridge in Danger*

---

*Houses undermined in Weardale*

---

*River still rising*

---

*More damage Feared*

The article reported:

> *Owing to the rapid thaw following the severe snowstorm, the Inhabitants of Croft and district are suffering a miniature deluge. Near Croft the water is four feet deep .....*
>
> *... No such floods have been known for a generation. The water is up to the steps of the Comet Inn, and up to the arches of Croft Bridge. Owing to the Tees being so much above its normal height, the Skerne where it joins with it is dammed back.*

The article continues to describe the mechanisms and effects of the flood:

> *The excessive volume of water in the Tees is accounted for by the fact that the hills and dales, now subjected to a rapid thaw, were pouring down the accumulation of snow left by a succession of heavy storms.*

From the evidence presented, it would appear that Flood [1881] was a catastrophic event on the River Tees with the Skerne escaping other than local 'damming' near the confluence. This major event is recorded at Yarm.

## 2.31. Flood [1886]

The Northern Echo, dated Monday 8 November 1886 reported on a severe gale affecting the North of England and part of the coast of Wales and in the Irish Channel on Saturday 6 November 1886, Flood [1886]. The article had dramatic headlines:

*Terrible shipping Disasters*

---

*Great Flood in the North*

---

*A Board school Wrecked*

---

*The Wear over its Banks*

---

*Street inundated at Darlington*

---

*Immense Damage*

The extent of the storm was extensive and the article gives accounts at locations including Middlesbrough, Hartlepool, Darlington, Sedgefield, Ferryhill and Yarm.

In respect of Darlington it was reported:

> *... The result was on Friday night the River Skerne had risen to an abnormal height and on Saturday morning overtopped its banks.*
>
> *... a great amount of water flooded into the streets, the people living in Clay-row and John Street being compelled to remove part of their furniture from the ground floor of their houses.*
>
> *... only those adjoining the bridge (in Clay-row) which passed over the Skerne were affected. The flooding here was caused by the river running on a level with the bridge.*
>
> *... At Clay-row the flooding was caused by the bursting of a drain, with the consequence that a volume of water above a foot deep flooded the houses on the lower side of the row from the bottom of Priestgate to near the Stonebridge.*
>
> *... At the north end of the town, above the much-talked-of obstructions in the river adjoining the ironworks, the land for several fields round was one ..... of water. A similar state of things prevailed in the south part of the town. The low-lying portion of the Public Park which adjoins the Skerne was flooded.*
>
> *... From thence up to the estuary of the river at Croft all the low-lying land had been flooded.*

It is interesting that the reporter only made passing comment about the *'much-talked-about'* obstruction in the river adjoining the ironworks. Thomas Smith, the Borough Surveyor reported to the Streets Committee in October 1884 on a similar issue. He had inspected the river on 7 October 1884 from Haughton Bridge to the Railway viaduct of the Stockton and Darlington Railway, and itemised numerous impediments to the free flow of the river, namely:

- From about 460 yards (420m) downstream of Haughton Bridge to Albert Road Bridge, the channel was very irregular and tortuous, with the width

varying and in some places 'exceedingly narrow'. At the same location, there was a large bed of rushes obstructing the flow during floods.

- Between the North Eastern Railway Viaduct and the new bridge of the Darlington Iron Company, the bed of the River was almost filled-in with slag.

- Near Albert Road Bridge, there were several Willow Trees.

- A temporary dam of slag had been constructed south of Albert Road Bridge.

- Near the Stockton and Darlington Railway Viaduct, slag had tumbled into the river bed off the adjoining slag tip.

Smith concluded that remedies were necessary to satisfy a complaint the Council had received from the Rural Sanitary Authority. Consequently he made proposals for extensive improvements to the channel, however his report is silent on the issues of responsibility and the morality of those causing the obstructions. The concept of the *'Polluter Pays Principle'* (PPP) appears not to have been conceived of at this time.

## 2.32. Flood [1900]

The Northern Echo, dated 28 October 1900 reported on the Flood [1900] to the effect that *'the Skerne was observed to be in a state of commotion' ... The Skerne was a torrent.* In summary, the following damage was caused:

- It overflowed its course at Priestgate and into Parkgate, Clay-row and the streets that ran-off those main thoroughfares.

- Houses were flooded in various streets surrounding lower Parkgate.

- Parkgate was impassable. The water ran to the width of several yards alongside the dwellings to the (s) north? of Councillor Oliver's shop and covering the street a little further on in Clay-row and beyond.

- Flooding was extensive at Haughton-le-Skerne and Croft.

- South Park was flooded on the lower levels.

The article confirmed that the level of the Tees was not abnormal, but at the Skerne confluence the water resembled boiling foam. Furthermore, the rainfall, according to the meteorological report taken at South Park on the Friday was 2.10 inches (53mm) or 210 tons per acre.

The Darlington and Stockton Times whilst reporting on the Flood [1903] in the edition appearing on 10 October, 1903 under the *'Street Scenes'* section stated that:

> *Several of the streets which touch the banks of the Skerne at Darlington were in flood yesterday, and were in a worse plight than was the case of the flood three years ago (1900).*

No Council Minutes could be found for Flood 1900.

## 2.33. Flood [1903]

The Darlington and Stockton Times, 10 October 1903 reported on *'Great Rainfall and Floods'* which occurred on the previous day 9 October 1903.

Pertinent extracts from the article are given in Appendix 25 from which the following conclusions can be drawn:

- The River Skerne had been extensively engineered prior to 1903 for commercial exploitation in order to benefit the various Mills.

- Flooding of the low lying streets occurred, including Clay Row, Parkgate and John Street.

- Max flood level, relative to ordnance datum is known or can be determined at the following locations:

⇒ Priestgate Bridge = 37.98m AOD (124.65)

⇒ Clay Row = 37.61m AOD

⇒ Parkgate (opp St Hilda's) = 37.91m AOD

On further examination it would appear that BEng No 412/1, untitled, but giving a longitudinal section of the river from John Street to Blackwell Mill relates to Flood [1903]. The drawing number is contemporaneous to the period, and the Weirs referred to in Winter's report correspond to the longitudinal section details. There is, however, a point of conflict should this be the case. The level at Priestgate Bridge is given as 124.62 ft (37.98m) in this report, whereas the scaled drawing value is 122.60 ft. (37.37m). From observation the longitudinal section appears to follow a logical sequence and 'looks' correct. The report only gives a single value, which may have been either a typing error or a level unrelated to Ordnance Datum. The value of 124.62 ft. (37.98m) at Priestgate Mill is very high and any flood of this magnitude would have been very severe indeed, albeit less than the Flood [1875].

The drawing referred to in relation to Flood 1903 is tabulated in Appendix 28.

Evidence of the 1903 flood is provided by the Borough Surveyor's report dated 29 February 1904 addressed to *The Chairman and Members of the Streets Committee* given in Appendix 29. In his report, George Winter, the Surveyor, refers to the flooding of the low-lying streets in the Borough adjoining the River and makes recommendations to prevent, as far as possible, future occurrences. Winter's report contains precise and accurate information about the configuration of the River Skerne in 1903. The location of weirs together with the differences in level between the top (upstream) and the bottom (downstream) are given. The purpose of the weirs is also explained.

Winter provides the top of weir level relative to ordnance datum (assumed to be Newlyn) at four locations. Perhaps even more importantly he records strategic information on the flood levels of the 10 October, 1903 storm, namely;

> *During the last flood the water level at Priestgate Bridge was 124.62* (assumed feet AOD).
>
> *... which is 15 inches (375mm) above the street level in Clay Row.*
>
> *... and three inches (75mm) above the street level in Parkgate opposite St Hilda's Church, and*
>
> *Whilst the flood level in John Street was two feet (610mm) below the flood level in the river at the Bridge.*

Using the primary evidence provided by Winters' report, Figure 2.25 was constructed to show a longitudinal section of the River Skerne from Blackwell Mill to John Street.

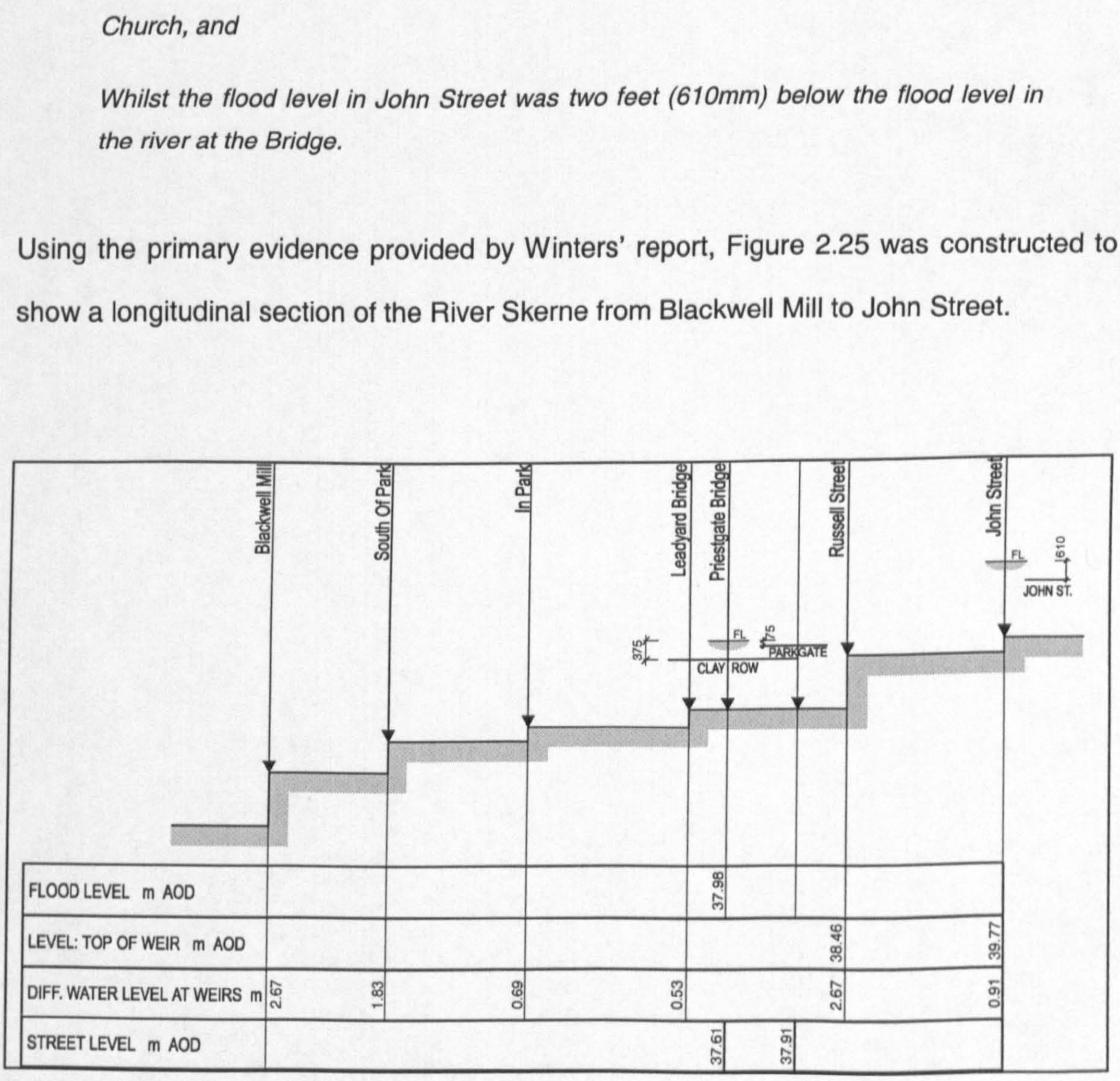



Figure 2.25 - River Skerne : Longitudinal Section

Using Winter's data the maximum flood levels attained at various strategic locations was calculated and are given at Table 2.25.

| Station | | Recorded Flood Levels | |
|---|---|---|---|
| | | ft | m |
| John Street | - downstream<br>- upstream | 134.60<br>134.70 | 41.03<br>41.06 |
| Overflow at Sawmills | | 133.70 | 40.75 |
| Chesnut Street | | 129.87 | 39.58 |
| Weir : upstream of Russell Street | - downstream<br>- upstream | 123.50<br>129.35 | 37.64<br>39.43 |
| Russell Street Bridge | | 123.35 | 37.60 |
| Mill Street | | 123.30 | 37.58 |
| Valley Street - off line of river | | 123.30 | 37.58 |
| Priestgate Bridge | | 122.90 | 37.48 |
| St Cuthbert's Bridge | | 123.70 | 37.70 |
| Kerb at Lord Nelson - off line of river | | 122.70 | 37.40 |
| Leadyard Bridge | | 122.11 | 37.22 |
| Victoria Road Bridge | | 121.30 | 36.97 |
| Polam Bridge | | 119.80 | 36.52 |
| Woodbridge Park (Geneva Road Bridge) | | 117.43 | 35.79 |

Table 2.25 - River Skerne : Flood Levels February 1903

No Council Minutes could be found for Flood [1903], however, Winters' Report given in Appendix 29 refers.

## 2.34. Flood [1924]

The Northern Echo, dated 2 June 1924, reported on Flood [1924] which had occurred the previous day, 1 June 1924. The storm appeared to affect the northern region of Northumberland and Durham. Darlington was flooded again from the River Skerne. The article confirmed that flooding to such an extent had not occurred for 25 years - Flood [1900].

The Skerne was out of bank at Priestgate mill and Clay-row was flooded. The flood level was stated to be within 'an inch or two' of Priestgate Bridge. Assuming that the reporter was referring to the bridge soffit, the actual flood level can be taken as:

Soffit 37.58 - 0.05 (2") = 37.53m AOD

The reporter makes the point that flooding had occurred yet again despite the fact that in recent years the river had been straightened! The Skerne overflowed its banks at both Haughton Bridge and Great Burdon Bridge. Cockerbeck was also very high, flooding gardens at Westbrook, whilst the southern half of Feethams cricket field was described as a 'water polo field' and was up to one foot deep. At Croft a number of fields were inundated, whilst at Neasham the water rose to the doors of houses on the village front. The newspaper also reports, in a separate article, that the rainfall was 2.08 inches (53mm) over 31 hours.

No Council Minutes could be found for Flood [1924].

## 2.35. Flood [1928]

The Northern Echo, dated 13 June 1928, reported on Flood 1928 and stated the flood to be the worst for 27 years in the Darlington area.

The Tees and Skerne both overflowed their banks at numerous places, with Neasham and Croft again badly affected. At Haughton-le-Skerne, the road was flooded to a depth of three to four feet and many houses were cut-off.

The article recorded a rainfall figure of 2.28 inches (58mm) in 24 hours.

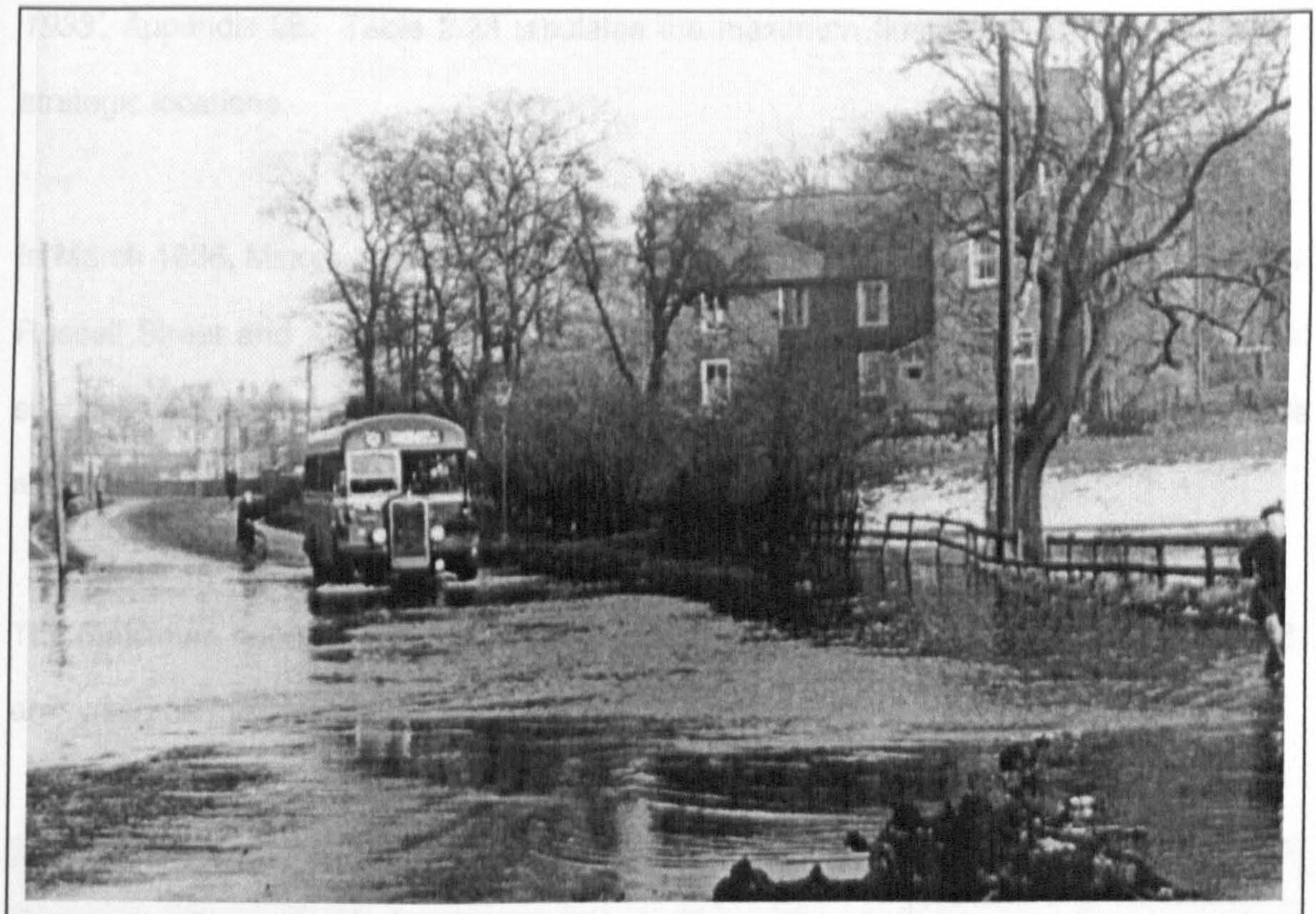


Figure 2.26 - Haughton-le-Skerne Flooding June 1928 (Northern Echo)

No Council minutes were found in respect of Flood [1928].

## 2.36. Flood [1933]

Ernest Minors AMICE, The Borough Surveyor to Darlington Borough Council, produced a plan and Longitudinal Section entitled *'Proposed Regrading of the River Skerne';* the details of the drawings are tabulated in Appendix 28. Levels are given in feet above Ordnance Datum. Endorsed upon the longitudinal sections is the profile of the Flood Level attained on 27 February 1933. No date of when the drawings were produced is given. Another drawing, again produced by Minors, bearing the same title gives the same base information as the longitudinal section. It would appear from inspection that this drawing was an early draft used to produce the other two.

Minors also produced a longitudinal section of the River Skerne from Geneva Road Bridge to Great Burdon Bridge recording the *'Level of Skerne during Flood February 27,*

*1933'*, Appendix 28. Table 2.28 tabulates the maximum flood level attained at various strategic locations.

In March 1936, Minors produced another longitudinal section of the River Skerne between Russell Street and Albert Road Bridges, Appendix 28. Endorsed upon the longitudinal section is the profile of the Flood Levels attained on 27 February 1933. As before, levels are in feet and related to Ordnance Datum.

The maximum flood levels attained at various strategic locations are given in Table 2.26, are based on the engineering plans and sections by Minors.

| Station | | Recorded Flood Levels | |
|---|---|---|---|
| | | ft | m |
| Great Burden Bridge | - upstream | 146.49 | 44.65 |
| | - downstream | 146.32 | 44.60 |
| Haughton Road Bridge | - upstream | 140.48 | 42.82 |
| | - downstream | 140.15 | 42.72 |
| Albert Road Bridge | | 134.56 | 41.01 |
| John Street Bridge | - upstream | 133.62 | 40.73 |
| | - downstream | 132.62 | 40.42 |
| Chesnut Street Bridge | - upstream | 128.79 | 39.26 |
| | - downstream | 128.57 | 39.19 |
| Russell Street Weir | | 128.19 | 39.07 |
| Russell Street Bridge | - upstream | 123.52 | 37.65 |
| | - downstream | 123.18 | 37.55 |
| East Street Bridge | - upstream | 122.51 | 37.34 |
| | - downstream | 122.26 | 37.26 |
| Priestgate Bridge | - upstream | 122.14 | 37.23 |
| | - downstream | 121.88 | 37.15 |
| Stone Bridge | - upstream | 121.35 | 36.99 |
| | - downstream | 121.34 | 36.99 |
| Leadyard Bridge | - upstream | 121.04 | 36.89 |
| | - downstream | 120.72 | 36.80 |
| Victoria Road Bridge | | 119.33 | 36.37 |
| Footbridge, end of Victoria Embankment | (Polam) | 117.62 | 35.85 |
| Geneva Road Bridge | - upstream | 116.37 | 35.47 |
| | - downstream | 116.23 | 35.43 |

Table 2.26 River Skerne : Flood Levels 27 February 1933

The drawings referred to in relation to Flood [1933] are tabulated in Appendix 28.

Only one reference, dated 11 May 1933, is recorded in Darlington Borough Council's Minute Book in respect of Flood [1933]. This is reproduced below:

> ***River Skerne - Weir.*** *- Submitted - A letter received from Messrs. Wm. Brown's Sawmills suggesting that in order to minimise the risk of flooding their property the weir in the River Skerne near the Russell Street bridge should be lowered.*
>
> *RESOLVED - That the Corporation agree to the lowering of the weir by one foot.*

## 2.37. Flood [1941]

Ernest Minors BSc AMICE, the Borough Surveyor to Darlington Borough Council, recorded maximum flood levels attained on 26-27 February 1941. The information took the form of spot levels given in imperial units and presented on a map of Darlington, at a scale of six inches to one mile (1:10560) (Appendix 28) and is summarised in Table 2.27.

| Station | Recorded Flood Levels | |
|---|---|---|
| | ft | m |
| **River Tees** | | |
| Broken Scar | 132.14 | 40.28 |
| **River Skerne** | | |
| Hurworth Place (Nr Comet Inn) | 102.24 | 31.16 |
| Nr Blackbanks House | 103.15 | 31.44 |
| Russell Street Bridge | 123.24 | 37.56 |
| Leadenhall Street/North Road Junction | 134.81 | 41.09 |
| John Street Bridge | 134.56 | 41.01 |
| Haughton Road (Speedwell Garage) | 141.54 | 43.14 |
| **Cocker Beck** | | |
| West Bridge (Cockerton) | 160.12 | 48.80 |
| **West Beck** | | |
| New Bridge | 190.87 | 58.18 |
| **Whessoe Road** | | |
| Whessoe Road/Longfield Road Junction | 180.40 | 54.99 |

Table 2.27 - Various Watercourses : Flood Levels 26-27 February 1941

No Council Minutes could be found for Flood [1941].

## 2.38. Flood [1946]

A drawing produced by the Borough Engineer entitled '*River Skerne, Regrading between Russell Street Bridge and Gas Works*' (Appendix 2.28) gives a longitudinal section of that section of the River. Levels are given relative to Ordnance Datum. Endorsed upon the longitudinal section is the profile of the Flood Levels attained in 1946 (precise date unavailable). The salient information can be seen in Table 2.28.

| Station | | Recorded Flood Levels | |
|---|---|---|---|
| | | ft | m |
| Weir, near Russell Street Bridge | | 127.33 | 38.81 |
| Chainage 6231 ft | | 127.50 | 38.86 |
| Chesnut Street Bridge | - downstream<br>- upstream | 127.82<br>128.31 | 39.96<br>39.11 |
| Chainage 6809 ft | | 129.03 | 39.33 |
| Cocker Beck | | 129.60 | 39.50 |
| Browns Sawmills - overflow | | 130.79 | 39.86 |
| John Street Bridge | - upstream | 131.23 | 40.00 |
| Chainage 7833 ft | | 131.60 | 40.11 |

Table 2.28 - River Skerne : Flood Levels 1946

Two references, dated 26 April 1946 and 30 May 1946 were discovered in the Darlington Borough Council Minute Book in respect of Flood [1946] as follows:

***Re-Grading of River Skerne.*** *- The Borough Surveyor reported that owners of property adjoining the old bed of the River Skerne were using it for tipping purposes, and he asked for the Committee's instructions regarding the scheme for re-grading the River Skerne.*

*RESOLVED - That the Finance Committee be requested to apply for the sanction of the Minister of Health to the borrowing by the Council of £16,000, being the*

*estimated cost of carrying into effect the scheme prepared by the Borough Surveyor for re-grading that section of the River Skerne between John Street and Russell Street.*

*(3) Streets. - RESOLVED - That the Town Clerk be directed and authorised to apply for the sanction of the Minister of Health to the borrowing by the Council of the sum of £16,000, being the estimated cost of carrying into effect the scheme prepared by the Borough Surveyor for re-grading that section of the River Skerne between John Street and Russell Street.*

## 2.39. Flood [1947]

A drawing produced by the Borough Engineer entitled *'River Skerne, Regrading between Russell Street Bridge and Gas Works'* (Appendix 28) gives a longitudinal section of that section of the River. Levels are given relative to Ordnance Datum. Endorsed upon the longitudinal section is the profile of the Flood Levels attained on 20 March 1947. The same drawing shows the maximum flood line of the Flood [1946], which is marginally less than Flood [1947]. The salient information is tabulated in Table 2.29.

| Station | | Recorded Flood Levels | |
|---|---|---|---|
| | | ft | m |
| Weir, near Russell Street Bridge | | 128.28 | 39.10 |
| Chainage 6131 ft | | 128.39 | 39.13 |
| Chesnut Street Bridge | - downstream<br>- upstream | 128.32<br>128.65 | 39.11<br>39.21 |
| Chainage 6809 ft | | 130.28 | 39.71 |
| Cocker Beck | | 131.50 | 40.08 |
| Browns Sawmills - overflows | | 132.66 | 40.35 |
| John Street Bridge | - downstream<br>- upstream | 133.28<br>133.35 | 40.62<br>40.65 |

Table 2.29 - River Skerne : Flood Levels 20 March 1947

No Council Minutes could be found in respect of Flood [1947].

## 2.40. Flood [1948]

On Monday 12 January 1948, the Northern Echo reported on Flood [1948] affecting Yorkshire and Darlington. The flood was a result of melting snow added to the already swollen rivers caused by heavy rain. The article confirmed that on 11 January 1948, the road at the Skerne Bridge at Haughton was flooded to a depth of 10 inches (300mm).

In a separate article on the same day, it was reported that flooding had occurred at Brown's Sawmills to a depth of six feet (1.80m). No other flooding locations were mentioned.

No Council Minutes could be found in respect of Flood [1948].

## 2.41. Flood [1949]

G S Short, the Borough Surveyor to Darlington Borough Council, recorded maximum flood levels attained in June 1949. The information was recorded on two drawings entitled *'River Skerne Re-grading'*, covering the stretch of the River from Aycliffe Railway Bridge to Haughton Road Bridge in Darlington (Appendix 2.28).

The salient issues in respect of the locations and corresponding maximum flood levels can be seen in Table 2.30.

| CS No | Station | Recorded Flood Levels | |
|---|---|---|---|
| | | ft | m |
| 1 | Aycliffe Railway Bridge | 211.85 | 64.57 |
| 2 | Shalters Bridge | 211.15 | 64.36 |
| 3 | Coatham Mundeville | 189.00 | 57.61 |
| 4 | Ketton | 178.60 | 54.44 |
| 5 | Skerningham | 171.60 | 52.30 |
| 6 | Barmpton | 162.24 | 49.45 |
| 7 | Burdon Bridge | 143.00 | 43.59 |
| 8 | Haughton Road Bridge | 139.50 | 42.52 |

Table 2.30 - River Skerne : Flood Levels June 1949

One reference, dated 20 September 1949 is recorded in Darlington Borough Council Minute Book in respect of Flood [1949] authorising some remedial works.

## 2.42. Flood [1950]

Ernest Minors AMICE, the Borough Surveyor to Darlington Borough Council, produced a Plan and longitudinal section entitled *'Proposed Regrading of the River Skerne'* (Appendix 2.28). Levels are given in feet above Ordnance Datum Table 2.32. Endorsed upon the longitudinal section is the profile of the Flood Level attained on 23 November 1950. Also shown on the same drawings are the Flood Levels attained on 27 February 1933 (Flood [1933]) which are marginally less than Flood [1950], together with the Dry Weather Flow recorded on 6 September 1934. The salient information of the flood on 25 November 1950 is tabulated in Table 2.31.

| Station | Recorded Flood Levels | |
|---|---|---|
| | ft | m |
| South end of Lake | 115.95 | 35.34 |
| Geneva Road Bridge | 117.00 | 35.66 |
| Footbridge | 117.29 | 35.75 |
| Footbridge (Polam Bridge) | 118.24 | 36.04 |
| Victoria Road Bridge | 118.93 | 36.25 |
| Leadyard Bridge | 120.54 | 36.74 |
| Stone Bridge | 121.19 | 36.94 |
| Priestgate Bridge | 120.01 | 36.58 |
| East Street Bridge | 122.08 | 37.21 |
| Russell Street Bridge | 123.00 | 37.49 |
| Weir (downstream of Russell Street Bridge) | 127.84 | 38.97 |
| Chesnut Street Bridge | 128.48 | 39.16 |
| Cockerbeck | 130.65 | 39.82 |
| John Street Bridge | 131.99 | 40.23 |
| Railway Bridge | 133.01 | 40.54 |
| Albert Road Bridge | 134.56 | 41.01 |
| 5 Arch Bridge | 136.71 | 41.67 |

Table 2.31 - River Skerne : Flood Levels 23 November 1950

No Council Minutes could be found in respect of Flood [1950].

The Northern Echo reported on 23 November 1950 that the main road at Haughton-le-Skerne was 12 inches (300mm) deep with water, making the road impassable. Furthermore, about two inches (50mm) of rain had fallen in 48 hours. The Skerne and Cocker Beck were flooded at several points. At South Park the river overflowed its banks and created a new lake.

## 2.43. Flood [1951]

No references could be found relating to Flood [1951] but the photograph below appeared in the Evening Dispatch.

Figure 2.27 - Haughton School, Darlington November 1951

## 2.44. Flood [1959]

The Wear and Tees River Board used a base drawing (Appendix 28) with a changed drawing number to record the maximum flood levels attained on 22 January 1959. This drawing gives a longitudinal section of the River Skerne from South Park Weir to just upstream of the Five Arch Bridge. The Longitudinal profile of the Flood [1959] is plotted over the full length of the section. The summarised data is given in Table 2.32.

| Station | Recorded Flood Levels | |
|---|---|---|
| | ft | m |
| South Park Weir | 115.30 | 35.14 |
| Geneva Road Bridge | 116.20 | 35.42 |
| Polam Bridge | 117.90 | 35.94 |
| Victoria Bridge | 118.80 | 36.21 |
| Leadyard Bridge | 120.80 | 36.82 |
| Stone Bridge | 121.00 | 36.88 |
| Priestgate Bridge | 122.50 | 37.34 |
| East Street Bridge | 123.00 | 37.49 |
| Russell Street Bridge | 123.80 | 37.73 |
| Weir, nr Russell Street Bridge | 127.80 | 38.95 |
| Chesnut Street Bridge | 128.40 | 39.14 |
| John Street Bridge | 132.70 | 40.45 |
| Skerne Bridge (£5 Note) | 133.00 | 40.54 |
| Albert Road Bridge | 134.30 | 40.93 |
| Forge Railway Bridge | 138.00 | 42.06 |
| Five Arch Bridge | 138.30 | 42.15 |

Table 2.32 - River Skerne : Flood Levels 22 January 1959

Only one reference, dated 17 November 1959, is recorded in Darlington Borough Council Minute Book in respect of Flood [1959]. This is reproduced below:

> ***B184. River Skerne** - 1 RUSSELL STREET WEIR - Submitted - A request from the Wear and Tees River Board that in order to improve the flow and reduce the water level of the River Skerne, they be allowed to make alterations to the weir at Russell Street.*
>
> *RESOLVED - That no objection be raised to such alterations being carried out at no expense to the Council and subject to a suitable indemnity being given.*
>
> *(2) LAND NEAR LEADYARD - The Borough Surveyor reported that the Board were preparing to build a small earth bank on land near Leadyard to stop flooding in this area.*
>
> *RESOLVED - That the Committee agree to the Board carrying out this work.*

The Northern Echo reported on 23 January 1959, that the Skerne had burst its banks at Aycliffe, flooded Haughton Church of England School and threatened low lying parts of the town. At Croft the river was running full, but not out of banks.

## 2.45. Flood [1963]

The Wear and Tees River Board (WTRB) used a base drawing (Appendix 28) with a changed drawing number to record the maximum flood levels attained on 6 March 1963. This drawing gives a longitudinal section of the River Skerne from South Park Weir to just upstream of the Five Arch Bridge. The Longitudinal profile of the Flood [1963] is plotted over the full length of the section. The summarised data is given in Table 2.33.

WTRB also produced a longitudinal section of the River Skerne from Victoria Road Bridge to Albert Road Bridge. Endorsed on the longitudinal section is the profile of Flood [1963]. Furthermore, the drawing bears a note to the effect that the maximum discharge of the flood was estimated to be 1750 cusecs.

| Station | Recorded Flood Levels | |
|---|---|---|
| | ft | m |
| Geneva Road Bridge | 117.40 | 35.78 |
| Victoria Road Bridge | 118.70 | 36.18 |
| Leadyard Bridge | 121.20 | 36.94 |
| Stone Bridge | 121.70 | 37.09 |
| Priestgate Bridge | 122.30 | 37.28 |
| East Street Bridge | 122.80 | 37.43 |
| Russell Street Bridge | 123.50 | 37.64 |
| Weir, nr Russell Street Bridge | 128.00 | 39.01 |
| Chesnut Street Bridge | 128.80 | 39.26 |
| John Street Bridge | 133.30 | 40.63 |

Table 2.33 - River Skerne : Flood Levels 6 March 1963

Archer (1992) recorded that:

> *Flooding along the length of the Skerne and through Darlington occurred in early March 1963 during a rapid thaw at the end of an extreme winter with more than two months' snow cover. However, in the year following the completion of the Improvement Scheme, the Skerne showed that it was not yet completely mastered.*

Only one reference, dated 22 October 1963 is recorded in Darlington Borough Council Minute Book in respect of Flood [1963]. This is reproduced below:

> ***B112. Park Place - Flooding -*** *Submerged - A petition received by the Mayor from residents in Park Place complaining about the flooding which occurred at times of heavy rainfall. The Borough Surveyor reported upon the matter and recommended that in view of the age of the property in the area it would be preferable to carry out temporary remedial works rather than a comprehensive scheme of surface water sewering. He submitted an estimate amounting to £650 of the cost of providing additional gullies and replacing those which were defective.*
>
> *RESOLVED - That the matter be considered when the rate estimates for 1964-65 are being prepared.*

The Northern Echo reported on the 6 March 1963 that both Croft and Neasham were almost entirely marooned the previous night. One resident stated that:

> *'My father told me that in 1881 they rose almost to the first floor windows of some homes' (at Croft).*

The Post Office at 12 Tees View, Hurworth Place had flood water over the door step. The Northallerton road (A167) was flooded. It was further reported that the Tees was 11 ft (3.35m) above its normal level near the pumping station in Coniscliffe Road.

## 2.46. Flood [1967]

The Northern Echo dated 18 October 1967 reported on the effects of Flood [1967]. The River Tees overtopped its banks in several places and the Skerne overflowed causing

flooding in the town. According to Archer (1992):

> *Floods occurred on 17 October and 6 November 1967. In the first, twelve houses and several commercial premises were affected on Lambton Street Darlington. The wet ground conditions caused a greater proportion of the rainfall to run off during the second event, causing more serious flooding: fifty-four properties over a thirteen-acre area were affected. Industrial and commercial premises and houses were flooded in Valley Street, John Street, Leadenhall.*

Parkgate was under water when the Skerne overtopped its banks. Flood water was six to seven feet (1.80m - 2.10m) deep in places, fields and roads near Croft and Neasham were flooded.

The rainfall was estimated to be 1.80 inches (46mm) over 16 hours.

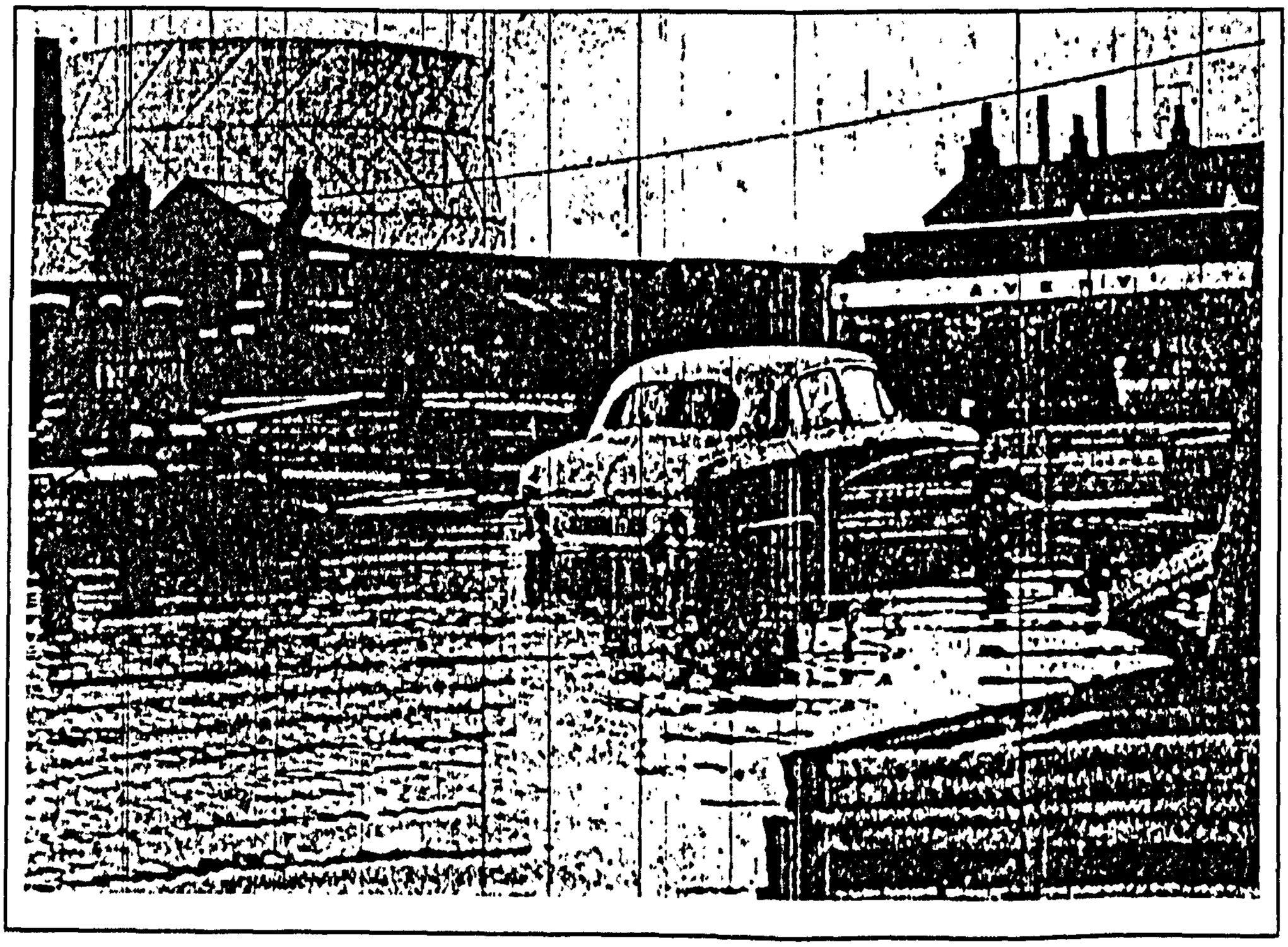


Figure 2.28 - Flooding at Brown's Sawmills 1967

No Council minutes were found in relation to Flood [1967].

## 2.47. Flood [1978]

The Northern Echo dated Friday, 29 December 1978 reported on Flood [1978], which resulted as a consequence of five days of rain. Darlington flooded at various locations including Burtree Lane and Haughton Road.

Figure 2.29 - Flooding Haughton Road, Darlington (Northern Echo 29 December 1978)

M Haley, The Borough Engineer to Darlington Borough Council, recorded maximum flood levels attained on 28 December 1978 at various locations within the urban area of the town. The information took the form of a series of spot levels in metric units and presented on a map of Darlington at a scale of six inches to one mile, (Appendix 28).

Table 2.34 tabulates the maximum flood levels attained at various strategic locations.

| Location | Max Flood Level (m) |
|---|---|
| **River Skerne:** | |
| Polam Bridge | 36.45 |
| Victoria Bridge | 36.76 |
| St Cuthbert's Bridge | 37.08 |
| John Street Bridge | 40.74 |
| Haughton Bridge | 43.34 |
| Great Burdon Bridge | 44.24 |
| **Cocker Beck:** | |
| Cockerton Bridge | 48.24 |
| **Baydale Beck:** | |
| Mowden Bridge | 48.75 |

Table 2.34 - River Skerne/Cocker Beck : Flood Levels 28 December 1978

The South Park gauging station recorded a discharge for the Flood [1978] equivalent to those of Flood [1963] and Flood [1967].

No Council Minutes could be found in respect of Flood [1978].

## 2.48. Flood [1979]

A significant flood was recorded by the EA in late March 1979. This followed a Winter of numerous severe snowstorms accompanied by rapid thaws. A heavy snowfall fell on 17 March with a corresponding thaw on 25 March. However, the Skerne was still swollen, and the ground saturated and still snow covered, according to Archer (1992). It is recorded that 40 to 50mm of rain fell on 28/29 March.

Residents at Brafferton were evacuated from their homes whilst in Darlington the river overtopped its banks onto the Ring Road and over the bridge at Priestgate. Haughton Road was covered to a depth of four feet (1.20m). Recorded property flooding was, however, limited. Homes at Spring Court, off West Beck, were flooded.

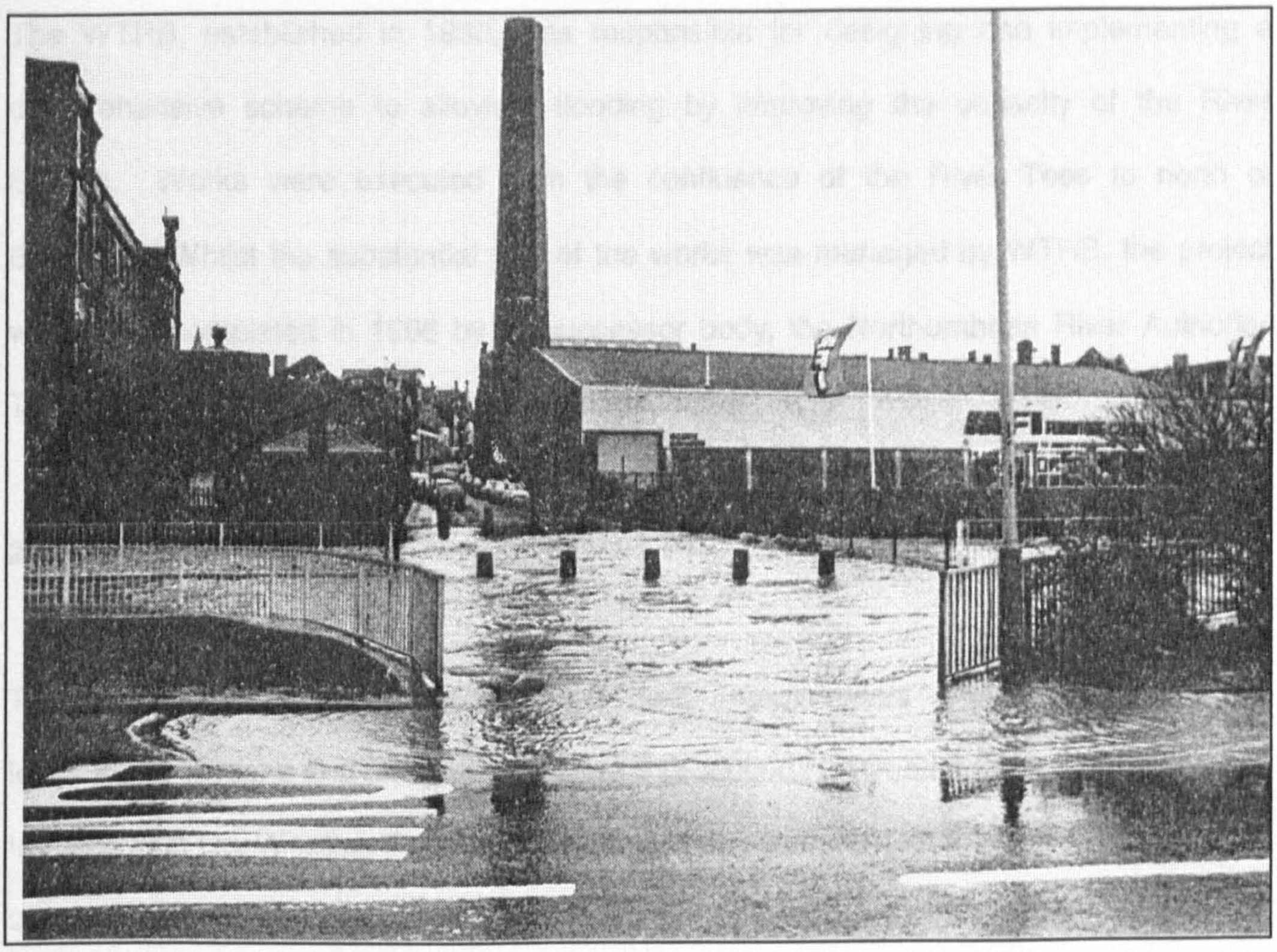


Figure 2.30 - Flood [1979] Priestgate Bridge (Photo : North of England Newspapers)

It is estimated from the photograph that the flood level at Priestgate Bridge is 38.10m AOD.

**Design Floods**

During the discovery process, to establish the extent and frequency of flooding of Darlington, three sets of information relating to 'Design Floods' were found:

- The first set was prepared by the Wear and Tees River Board (WTRB) and dated 1952 and 1953.
- The second set was also prepared by WTRB and dated 1964.
- The third set by Northumbrian River Authority and dated 1969 and 1970.

The WTRB, established in 1950, was responsible for designing and implementing a comprehensive scheme to alleviate flooding by improving the capacity of the River Skerne. Works were executed from the confluence of the River Tees to north of Bradbury. Whilst the substantial part of the works was managed by WTRB, the project was finally completed in 1966 by its successor body, the Northumbrian River Authority. The following is an analysis of the information found.

## 2.49. Design Flood [1952]

Ten drawings, all entitled *'River Skerne General Improvements - Part 2'*, showing plans, longitudinal sections and cross sections, were produced. Estimated flood levels are given together with Dry Weather Flows (DWF) on specific dates. A note appears on most of the drawings stating *'All levels to be referred to Bench Marks shown on Site Plan 3/8-257, based on Newlyn Datum'*. All of the drawings are stamped with the Wear & Tees River Board Title Block which has a Plan Number and the Date. The drawings were found in the Borough Engineer's Drawing Archive. It is suspected that the two authorities collaborated on the project, since precise details of numerous highway bridges appear on the drawings. The drawing schedule is given at Appendix 28.

Table 2.35 gives in summary the estimated flood levels at specific chainages which have been extracted from five of the drawings referred to in Appendix 28.

| Drg No | CS No | Chainage/Location | Estimated Flood Level | |
|---|---|---|---|---|
| | | | ft | m |
| S/8·2 59 20 Oct 1953 B Eng 2081/ 26 | 45 | 14,500 | 117.6 | 35.84 |
| | 46 | 14,800 | 117.9 | 35.94 |
| | 47 | 15,100 | 118.1 | 36.00 |
| | 48 | 15,400 | 118.3 | 36.06 |
| | 49 | 15,700 | 118.5 | 36.12 |
| S/8·2 60 17 Sept 1953 B Eng 2081/ 26 | 50 | Not Given | 118.6 | 36.15 |
| | 51 | Not Given | 118.8 | 36.21 |
| | 52 | Not Given | 118.9 | 36.24 |
| | 53 | Not Given | 119.1 | 36.30 |
| | 54 | Not Given | 119.4 | 36.39 |
| S/8·2 61 25 July 1952 B Eng 2081/ 26 | 55 | 17,500 | 119.6 | 36.45 |
| | 56 | 17,773 | 119.8 | 36.52 |
| | 57 | 18,100 | 120.0 | 36.58 |
| | 58 | 18,400 | 120.3 | 36.67 |
| | 59 | 18,700 | 120.5 | 36.73 |
| | 60 | 19,000 | 120.7 | 36.79 |
| | 61 | 19,400 | 121.1 | 36.91 |
| | 62 | 19,700 | 121.4 | 37.00 |
| S/8·2 62 25 July 1952 B Eng 2081/ 34 | 63 | 20,027 : Low Mill Foundry | 121.7 | 37.09 |
| | 64 | 20,576 : St Cuthbert's Bridge | 122.6 | 37.37 |
| | 65 | 20,816 : Opposite Priestgate Mill | 122.7 | 37.40 |
| | 66 | 21,300 : Opposite Valley Street | 123.7 | 37.70 |
| | 67 | 21,609 : Russell Street Bridge | 124.3 | 37.89 |
| | 68 | 21,992 | 129.0 | 39.32 |
| | 69 | 22,307 | 129.5 | 39.47 |
| | 70 | 22,600 | 130.4 | 39.75 |
| | 71 | 22,970 | 131.6 | 40.11 |
| | 72 | 23,320 | 134.6 | 41.03 |
| S/8·2 63 20 Octob er 1953 B Eng 2081/ 35 | 73 | 23,600 | 135.0 | 41.15 |
| | 74 | 23,900 | 135.5 | 41.30 |
| | 75 | 24,134 : Main Railway Bridge | 135.6 | 41.34 |
| | 76 | 24,300 | - | - |
| | 77 | 24,560 : Albert Road Bridge | - | - |
| | 78 | 24,800 | - | - |

Table 2.35 - River Skerne : Estimated Flood Levels, July 1952

Two drawings were dedicated to the bridges on the reach Oxneyfield Bridge to Great Burdon Bridge. Four bridges, however, were excluded from these drawings but were treated in the general cross-section drawings. Table 2.36 gives in summary the estimated flood levels at the bridge locations. For ease of reference, the four omissions have been included in the table in italic type.

| Drg No | CS No | Chainage/Location | Estimated Flood Level | |
|---|---|---|---|---|
| | | | ft | m |
| S/8·2 65, 24 July 1952 BEng 2081/ 26 | | 497 : Oxneyfield Bridge | - | - |
| | | 11,860 : 16" Sewer, nr Snipe Bridge | - | - |
| | | 14,260 : Footbridge & Weir, South Park | 117.5 | 35.81 |
| | | 15,855 : Geneva Road Bridge | 118.6 | 36.15 |
| | | 19,276 : Victoria Road Bridge | 120.0 | 36.58 |
| | | 20,103 : Leadyard Bridge | 121.8 | 37.12 |
| | *64* | *20,576 : St Cuthbert's Bridge* | *122.6* | *37.37* |
| | | 20,961 : Priestgate Bridge | 122.9 | 37.46 |
| | | 21,167 : East Street Bridge | 123.4 | 37.61 |
| | *67* | *21,609 : Russell Street Bridge* | *124.3* | *37.89* |
| | | 22,427 : Chesnut Street Bridge | 130.0 | 39.62 |
| WTR B S/8· ..... 20 Octob er 1953 BEng 2081/ 38 | | 23,438 : John Street Bridge | 134.7 | 41.06 |
| | | 23,955 : 2/18" dia Gas Mains | 135.5 | 41.30 |
| | | 24,030 : Access Bridge | 135.6 | 41.33 |
| | *75* | *24,134 : Main Railway Bridge* | 135.6 | 41.34 |
| | *77* | *24,560 : Albert Road Bridge* | - | - |
| | | 26,795 : Five Arch Bridge | - | - |
| | | 30,239 : Footbridge | - | - |
| | | 31,047 : Haughton Bridge | - | - |
| | | 33,155 : Access Bridge | - | - |
| | | 33,292 : Footbridge | - | - |
| | | 36,148 : Great Burdon Bridge | - | - |

Table 2.36 - River Skerne : Bridges - Estimated Flood Levels, July 1952

Two additional drawings were produced (Appendix 28), giving a continuous longitudinal section from the South Park Weir to Great Burdon Bridge. The combined drawing shows the following information.

- Chainages in feet, the location of cross-sections and strategic structures including main services.
- Surface and soffit levels of bridges.
- River bed levels.
- Embankment levels for both banks.
- Proposed bed gradients between:

  ⇒ South Park Weir to Geneva Road Bridge

  ⇒ Main Line Railway Bridge to Great Burdon Bridge

- Estimated Flood Level from South Park Weir to the Main Line Railway Bridge (Five Arch Bridge).

No Council Minutes could be found in respect of Design Flood [1952].

## 2.50. Flood [1964]

The Wear and Tees River Board produced a longitudinal section of the River Skerne from Victoria Road Bridge to Albert Road Bridge in March 1964 (Appendix 28) showing the levels of both banks and the river bed. Endorsed on the drawing a note:

*Estimated 1750 cusec flood* _____

*Flood of March 1963 (Flood [1963])* .....

Table 2.37 gives in summary the estimated flood levels at specific locations.

| Station | | Estimated Flood Levels | |
|---|---|---|---|
| | | ft | m |
| Victoria Bridge | | 121.20 | 36.94 |
| Leadyard Bridge | | 122.35 | 37.29 |
| Stonebridge | | 123.48 | 37.64 |
| Priestgate Bridge | | 124.00 | 37.80 |
| East Street Bridge | | 124.20 | 37.86 |
| Russell Street Bridge | | 125.70 | 38.31 |
| Weir, nr Russell Street | | 129.30 | 39.41 |
| Chesnut Street Bridge | - downstream<br>- upstream | 130.70<br>130.80 | 39.84<br>39.87 |
| John Street Bridge | | 135.70 | 41.36 |
| 5 Arch Bridge (Main Line Railway Bridge) | | 136.70 | 41.67 |
| Albert Road Bridge | | 137.30 | 41.85 |

Table 2.37 - River Skerne : Estimated Flood Levels, 1964

No Council Minutes could be found in respect of Flood [1964].

## 2.51. Design Flood [1969]

Northumbrian River Authority produced two drawings of the River Skerne in May 1970, entitled *'Proposed Channel Improvement - Cross Sections from Russell Street Bridge'*, (Appendix 28).

The drawings give a series of cross sections at fifteen locations on the river from Russell Street Bridge to John Street Bridge. Shown on a number of cross sections is the maximum flood level attained by the Design Flood [1969] together with Dry Weather Flows on specific dates. A horizontal line is shown on each cross section which represents a

flood discharging at 1870 cusecs. It should be noted that this is a higher value than that used in Flood 1964 of 1750 cusecs.

The estimated flood levels at specific locations are given in Table 2.38.

| Station | Estimated Flood Levels | |
|---|---|---|
| | ft | m |
| Russell Street Weir | 128.0 | 39.14 |
| 300 ft | 128.8 | 39.26 |
| 600 ft | 129.5 | 39.47 |
| 815 ft : Chesnut Street Bridge | 130.4 | 39.75 |
| 900 ft | 131.0 | 39.93 |
| 1200 ft | 131.7 | 40.14 |
| 1350 ft | 132.0 | 40.23 |
| 1400 ft | 132.2 | 40.29 |
| 1450 ft | 132.5 | 40.39 |
| 1500 ft | 132.8 | 40.48 |
| 1550 ft | 133.0 | 40.54 |
| 1600 ft | 133.2 | 40.60 |
| 1725 ft | 133.9 | 40.81 |
| 1820 ft : John Street Bridge | 134.2 | 40.90 |

Table 2.38 - River Skerne : Estimated Flood Levels 1969

No Council Minutes could be found in respect of Flood [1969].

# 3.0 GEOLOGY

The Darlington area of North East England, the subject of this study, is mainly underlain at depth by strata belonging to the Upper Carboniferous (Namurian & Westphalian) and the Permian Periods (Figure 3.2). In addition, the south-eastern part of the area is occupied by hills of the early Triassic Period (Sherwood Sandstone Group, *partim*).

These rocks of the Upper Palaeozoic and Lower Mesozoic are extensively masked by drift deposits. These drift sequences are largely of Quaternary and Holocene glacial and post-glacial origin which form a thick covering, locally up to about 50m. In total, information was gathered from 1029 boreholes with 240 penetrating the solid geology. Figure 3.1 tabulates the details of the boreholes used for the solid geology.

The solid geology covered by the sub-region scoping area shown in Figure 2.2 was examined to determine what influence, if any, the underlying water bearing rocks had on the location of the settlement of Darlington. Furthermore, consideration was given as to how these influences would change with respect to time.

The interpretation of the solid geology forms part of collaborative work with Dr A H Cooper (BGS) which is currently in press.

This investigation was carried out in two parts:

- Initially the localised examination of the geology and hydrogeology of the south-eastern sector of Darlington.
- A more comprehensive review of the sub region area by the collection of extensive borehole information and subsequent interpretation of the resultant database.

The location of boreholes that penetrate the solid geology and their sources are given in Figure 3.1. In addition to these, several others are retained by the BGS on a confidential basis.

There is historical evidence that the south-eastern part of Darlington suffers from subsidence that may have been related to the presence of Permian gypsum deposits beneath the area. Gypsum is a readily soluble rock, in which cavities and caves may be created. Funnelling of the overlying glacial deposits into these voids can result in localised subsidence. The natural or induced groundwater flow in the area can cause enhanced rates of gypsum dissolution, also resulting in extensive subsidence. In addition to this, lowering of the groundwater table may trigger the occurrence of subsidence. A sample of gypsum retrieved from the surface of a hillside near Zaragoza in Northern Spain is shown in Appendix 30. Numerous small channels are evident on the surface due to dissolution caused by rainfall discharging down the hillside.

The rockhead geology of the area represents the former topographic land surface prior to the deposition of the concealing drift. The strata of the rockhead surface may be of variable age depending on the history of its development and the nature of the buried landscape. Presently, exposed rock areas towards the west of the area are still being eroded while some alluvial and estuarine covered areas have been buried for a long time and are still being buried by recent deposition.

The topography of the rockhead has been constructed as a contour plot using borehole and natural exposures. The information has been derived from the borehole database constructed during this research, published geological maps and the OS information. The map has not been checked against the present land surface; consequently, it may include inaccuracies in the west where the superficial deposits are thin. For most of the area, except along parts of the Tees, the drift deposits are thick and the rockhead contour map may be considered a reasonable, but interim, interpretation of the real situation (Figure 3.3).

The rockhead contour map (Figure 3.3) shows the escarpment of the Raisby and Ford Formations rising sharply to the north-west corner of the area and slightly to the south-west. This escarpment is cut through by the valley of the River Tees approximately along east-west grid line 514. East of the buried Permian escarpment, most of the area forms a buried undulating plain varying in elevation between about 10m AOD and +10m AOD. An area to the east of the area is suggested by the contouring package to lie below -20m OD. However, this 'low' area appears to be an artefact of the contouring package and parameters used since there are no boreholes actually in this sector. The rockhead contours also highlight several other isolated basinal areas below OD. These include an area in the south of Darlington Town where boreholes for this study have proved the existence of gypsum deposits and this basinal area in the bedrock may have been caused by the dissolution of the gypsum and the subsequent collapse of the overlying strata.

## 3.1. Solid Geology

The generalised geological sequence of Permian and Triassic rocks that underlies the Darlington area is indicated in Table 3.1.

| | | | Thickness |
|---|---|---|---|
| TRIASSIC | | **Sherwood Sandstone Group** (formerly Bunter Sandstone), red-brown fine to medium-grained sandstone. | c. 250m |
| PERMIAN | | **Roxby Formation** (formerly Upper Marl); red-brown calcareous mudstone (marl) with subordinate gypsum beds and up to about 8m of gypsum or anhydrite at its base. | 7 - 50m |
| | | **Seaham Formation** (formerly Upper Magnesian Limestone): pale grey calcitic dolomite mainly in thin beds. | 14 - 20m |
| | | **Edlington Formation** (formerly Middle Marl): red-brown calcareous mudstone (marl) with gypsum beds and up to about 30-40m of gypsum or anhydrite at its base. | 6 - 53m |
| | | **Ford Formation** (formerly Middle Magnesian Limestone): pale grey and yellow dolomitic limestone. | 8 - 70m |
| | | **Raisby Formation** (formerly Lower Magnesian Limestone): pale grey and yellow dolomitic limestone. | 10 - 47m |
| | | **Marl Slate formation,** calcareous bituminous mudstone. | 0 - c.2m |
| | | **Basal Permian Yellow Sands,** yellow fine to medium-grained sand of aeolian origin. | 0 - c.6m |
| CARBONIFEROUS | | **Carboniferous rocks, undivided,** sandstone, mudstone, siltstone and limestone (Thick tilted sequences beneath the Permian strata). | |

Table 3.1 - The Generalised Geological Succession of Permian and Triassic Rocks in the Darlington Area

### 3.1.1. Sherwood Sandstone Group (Triassic)

The Triassic Sherwood Sandstone Group forms the bedrock over 30% of the south-eastern area of the district and comprises red-brown fine to medium-grained sandstones forming a sequence up to 250m thick. This sandstone forms the main aquifer in this region, but it is heavily covered by superficial deposits. The exceptions are in the south of the district where it forms a slightly elevated buried ridge and therefore outcrops adjacent to the River Tees (NZ 430 510).

### 3.1.2. Zechstein Group

The marine Permian sequence all belongs to the Zechstein Group and this stratigraphical nomenclature is also used in the North Sea Basin, the Netherlands and in Germany. The group names that were proposed by Smith (1974) do not work well for the sequence stratigraphy because they relate to sedimentary cycles proven only in deep boreholes; therefore Smith's groups have not been generally used outside of a few studies in northern England. The Zechstein Group includes all the formations between the Marl Slate Formation (or Raisby Formation if that is missing) and the base of the Sherwood Sandstone Group. The Basal Permian Sands Formation (or Yellow Sands Formation) belongs to the largely terrestrial Rotliegendes Group that underlies the Zechstein Group. The distribution and development of the Zechstein Group in the Darlington area is partly constrained by the pre-Permian topography developed on the underlying Carboniferous strata. As a consequence of this topography, the Permian sequence onlaps against buried hills of Carboniferous rock both in the north of the district and to the south. Just south of the district (Figure 3.2) most of the Permian sequence wedges out against a major bedrock high coincidental with the Middleton Tyas Anticline formed in the underlying Carboniferous rocks. To the north of Darlington, borehole information suggests that hills of Carboniferous strata perforate the Permian sequence.

### 3.1.3. Roxby Formation (including the Billingham Anhydrite Formation)

The Roxby Formation comprises a sequence of massive gypsum or anhydrite overlain by calcerous and gypsiferous mudstone. The gypsum/anhydrite deposits are usually referred to as the Billingham Anhydrite Formation, but for practical purposes these strata cannot be separated from the Roxby Formation at outcrop, so the description is inclusive. The gypsum and anhydrite of the Billingham Formation occur at the base of the Roxby Formation forming a unit that ranges in

thickness from 3 to 8m (Table 3.2), except where it has been dissolved and may be absent (Figure 3.5). Gypsum ($CaSO_4.2H_2O$), or the residue beds left after the dissolution of the gypsum are present in the outcrop area of the Roxby Formation, but downdip away from the outcrop the rock passes into anhydrite ($CaSO_4$ - the anhydrous form of calcium sulphate). The borehole data suggest that the gypsum in the Roxby Formation is largely dissolved away where it comes to outcrop; however, in the area to the south-east of Darlington and where there is a cover of the Sherwood Sandstone Group (eg NZ 435 507) gypsum is present and passes rapidly into anhydrite downdip to the east. The sequence overlying the Billingham Formation gypsum is composed of calcareous mudstone with some interbedded gypsum. Towards the top of this unit beds of sandstone are commonly present interbedded with the mudstone. The total thickness of the Roxby Formation ranges up to 50m in the deep boreholes in the west of the district, but at the edge of the Sherwood Sandstone Group it is more likely to be around 25-30m thick. However, the logs of boreholes in fairly close proximity to the north-east of Darlington suggest an 11-49m range. This variation may be a function of the way the holes have been logged, or it may suggest thickening of the sequence due to foundering of strata caused by the dissolution of the underlying evaporites.

### 3.1.4. Seaham Formation

This formation is composed of dolomite and dolomitic limestone, typically in thin to medium bedded units. The beds are typified by the fossil alga *Calcinema permiana* that can commonly be identified in borehole cores and chippings. The formation varies in thickness, at and near outcrop, from about 15 to 20m (Table 3.2), but in the deep boreholes to the east, it is much thinner reaching only 1.68m in thickness in Borehole No 3518·9501 (NZ 435964 518562). The formation may also be thickened where the strata have foundered due to the dissolution of the underlying evaporites. Some of the cores drilled into the Seaham Formation,

such as Borehole No 2912·2902 (NZ 429294 512967), show the complete brecciation of the strata due to this collapse.

### 3.1.5. Edlington Formation (including the Hartlepool Anhydrite Formation)

The Edlington Formation varies in thickness from about 6m, where all interbedded evaporite deposits have been dissolved away to a maximum of nearly 53m where the Hartlepool Anhydrite Formation is complete. For practical reasons, the mapped Edlington Formation at outcrop also includes the gypsum and anhydrite deposits of the Hartlepool Anhydrite Formation. This is because the Hartlepool Anhydrite Formation is partly dissolved towards the outcrop making it very difficult to separate from the bulk of the Edlington Formation. Where no dissolution has occurred, the Hartlepool Anhydrite Formation includes up to 43m of anhydrite (Borehole No 3311·2301) (NZ 433280 511390). Elsewhere to the north of the study area, the formation is about 30m thick. When anhydrite is hydrated to gypsum by groundwater in the near-surface zone, it can expand by up to 63% (Mossop & Shearman, 1973) and it is possible that a greater thickness of gypsum could exist. However, the hydration can also involve the production of sulphate-rich fluids that can migrate and lead to precipitation of gypsum in adjacent formations (Shearman et al, 1972) and the removal of gypsum from the originating formation. It is probable that the maximum thickness of gypsum present at outcrop was between 30 and 43m, but hydration may have produced even greater thicknesses.

Little is known about the original thickness or geometry of the anhydrite deposits. However, both Smith (1989, 1995) and Tucker (1991) interpreted the Hartlepool Anhydrite Formation as a wedge-shaped deposit formed against the topography of the underlying and adjacent Ford Formation reef. However, their model was for the Durham Coastal area and farther south the reef facies has not been recognised. There is a likelihood of original thickness variation being present in

the Darlington area, but the evidence is not very good. It is possible that the 43m thickness proved to the east of Darlington is near to the maximum and that the wedge thins both to the west and east.

The actual thickness of the Hartlepool Anhydrite Formation (present mainly as gypsum beneath Darlington) is largely controlled by the way the rock has been subsequently dissolved, where rapid thickness variations from 8.0m to 19.5m occur within short distances and the overlying rock is brecciated. These features suggest that the Hartlepool Anhydrite Formation as gypsum has partially dissolved and may still be dissolving beneath the area. The thickest deposits (18-19.5m) have been proved in the southern part of Darlington. Borehole No 2912·9801, BGS Geneva Borehole (NZ 429900 512870) and Borehole No 2913·1104 (NZ 429108 513198). However, between these two holes, the gypsum has dissolved to a residual 13.0m thickness and the overlying strata have consequently collapsed and brecciated (eg Borehole No 2912·2902, NZ 429294 512967). These brecciated collapsed areas are on the flank of the Darlington Syncline (Figure 3.2) adjacent to a major east-west fault. To the north of the syncline, a gypsum thickness of around 12m has been proven in Borehole No 3116·7801 (NZ 431742 516862). There is no borehole information for the thickness of the gypsum in the core of the syncline; it may possibly be thicker than that proved on the flanks, depending on the local groundwater flow and the amount of dissolution. Towards the west the gypsum has dissolved and the amount present in boreholes decreases rapidly. Borehole No 2813·3301 (NZ 428331 513386) proved only about 4m of gypsum. Borehole No 2815·2301 (NZ 428263 515328) proved *15m of red marl with gypsum bands.* To illustrate the fact that this borehole still includes gypsum, a nominal thickness of 1.0m of gypsum is indicated for this site on Figure 3.6.

Above the gypsum or anhydrite of the Hartlepool Anhydrite Formation, there is an

irregular sequence of red-brown calcareous and gypsiferous mudstones and siltstones. These range in thickness from zero-c15m (possibly 30m in the east of the area), Most typically they are 6-10m thick. The zero recording possibly indicates a washout or collapse structure.

### 3.1.6. Ford and Raisby Formations (undivided)

For practical purposes, the Ford and Raisby Formations are considered together as they are both dolomitic units and in the majority of boreholes, cannot be separated. In Yorkshire to the south of the study area, they are not separated, but mapped as the Cadeby Formation, divided into two members. Only a few boreholes in the study area penetrate the full thickness of the Ford and Raisby Formations. Five kilometres south of Darlington the two formations are 84m in thickness (NZ 429020 509530) and about six kilometres north of Darlington they attain a thickness of 69m (NZ 428032 521320). Elsewhere, the upper part of the formation is truncated at rockhead and the proven thickness varies from 5-82m. This variation is not consistent and probably reflects variations in the topography of the pre Permian unconformity, with or without variation in the thickness of the Basal Permian Sands Formation. Boreholes arrayed in close proximity to each other show thickness variations of about 20m even though the topography of the rockhead is relatively slight. Large variations in the level of the basal unconformity are indicated by the 'hills' of Upper Carboniferous strata that penetrate through parts of the Permian sequence in the north of the district. These distinctive islands outcrop as inliers of Carboniferous rocks with Ford Formation and higher strata banked against them. In the core of the Darlington Syncline beneath the town of Darlington the combined thickness of the Ford and Raisby formations should attain a thickness, probably between 70m and 80m, providing there are no major topographical features associated with the Upper Carboniferous Unconformity.

### 3.1.7. Marl Slate Formation

The Marl Slate Formation is very thin and has not been differentiated on the generated geological map (Figure 3.2). It lies at the base of the Zechstein Group and comprises 0-about 2m of carbonaceous dolomitic mudstone commonly with a fish and/or plant fossil assemblage. To the east of the district it is well-developed and proved in many boreholes. To the west, it laps onto and around both the buried land surface composed of weathered Carboniferous rocks and the Basal Permian Sands Formation.

### 3.1.8. Basal Permian Sands Formation

Only a very small area of Basal Permian Sands Formation was mappable in the Darlington area (Figure 3.2). It lies at the base of the Raisby Formation and probably only reaches a few metres in thickness. The Basal Permian Sands Formation represents the feather edge of the early Permian Rotliegendes Group and comprises mainly of wind-blown sand preserved as lenticular seif sand dunes that were subsequently buried beneath the Zechstein Group (Smith, 1974).

## 3.2. Revision of the Published Map

The examination and tabulation of the borehole information have permitted a complete revision of the geological map based on a new understanding of the structure of the area. The published geological map for Darlington (Stockton Sheet 33, British Geological Survey, 1987) has been changed as a direct consequence of this research, but the broad distribution of the outcrop and the sequences shown on that map were approximately correct. The major changes to the previous maps concern the area immediately beneath Darlington and to the south of the town. Here the published map showed an outlier of Permian Upper Marl = Roxby Formation (PUM) that should actually have been labelled as an inlier of Permian Middle Marl = Edlington Formation (PMM) according to the large-scale

maps of the area. This has been reinterpreted as a faulted syncline. The new geological map is shown in Figure 3.2B with the east-west trending Darlington Syncline running beneath the town of Darlington. Figure 3.2B shows the distribution of the boreholes that have constrained the construction of the outcrop pattern of the map. The other constraints have been derived from the study of the bedrock contours and their integration with structure contours derived for five levels in the stratigraphy.

## 3.3. Structure contour maps

Five structure contour maps were constructed from the borehole and outcrop information, these are:

- Figure 3.7 Top of Roxby Formation/base of Sherwood Sandstone Group.
- Figure 3.8 Top of Seaham Formation/base of Roxby Formation.
- Figure 3.9 Top of Edlington Formation/base of Seaham Formation.
- Figure 3.10 Top of Ford Formation/base of Edlington Formation.
- Figure 3.11 Top of Carboniferous/base of Permian Raisby Formation.

In constructing the structure contour maps, the levels above and below that being constructed helped to constrain the interpretation of the geology. Other datasets were also utilised to produce the maps. Unpublished work done by D B Smith was used for the construction of the contours for Figure 3.11 showing the top of the Carboniferous/base of the Permian Ford Formation. His structure contours for the area showed the western extension of the Darlington Syncline mapped on the adjacent Barnard Castle geological map (Sheet 32, British Geological Survey 1969). The eastward extension of this syncline coincided with a westerly direction in the boundary between the Edlington Formation and

the overlying Seaham Formation mapped on the original Stockton Sheet (Sheet 33, British Geological Survey, 1987, also see Figure 3.2). The intersections proved in the boreholes for the area suggested that the syncline continued eastwards affecting all the strata up to and including the Sherwood Sandstone Group. The boreholes and structure contours also suggested that the southern limb of the syncline abutted a normal fault throwing down to the south (Figure 3.2). Another change suggested by the structure contour information was the repositioning of the north-east trending fault that cuts the Sherwood Sandstone Group near Croft in the south of the district. This fault has been repositioned with the same trend, but a few hundred metres to the south-east from its position on the existing published map.

## 3.4. Sample Cross-sections

The details of the structure are shown in three cross-sections derived from the structure contour information, borehole, outcrop and rockhead datasets, these are:

- Figure 3.12 NNW-SSE section through Darlington.
- Figure 3.13 N-S section through Darlington.
- Figure 3.14 E-W section through Darlington.

All these sections were constructed with a horizontal scale of 1:50,000 and a 10-times vertical exaggeration (1:5,000 vertical scale). This vertical exaggeration has the effect of making faults look near-vertical and structural dips look much steeper than they actually are. This should be borne in mind when viewing the cross-sections.

### 3.4.1. NNW-SSE section through Darlington (Figure 3.12)

This cross-section illustrates the Darlington Syncline approximately beneath the centre of Darlington and the River Skerne. The dips on the limbs of the syncline

are probably only a few degrees in magnitude (the dip shown on the cross-section is increased by the vertical exaggeration factor). Here the Edlington Formation appears to be thick to the south of Darlington on the south limb of the Darlington Syncline and against the faulted graben formed by the east-west fault and the north-east trending fault through Croft. That the gypsum (Hartlepool Anhydrite Formation, Figure 3.6) is fairly thick on the south side of Darlington is shown by the boreholes at Skerne Park and this is reflected in the thickness of the Edlington Formation here. To the north of Darlington, the cross-section suggests that the gypsum in the Edlington Formation is thinner. The Darlington Syncline preserves a core composed of the Seaham and Roxby Formations. The borehole data suggest that the Billingham Anhydrite Formation mapped as part of the Roxby Formation is actually dissolved away. At the southern end of the section there is an indication of thinning in the Permian sequence as it laps onto the buried topography of the underlying Carboniferous rock. The cross-section also shows that the thick glacial deposits that cover the area of Darlington thin southwards towards the course of the River Tees. In the vicinity of the River Tees, the river down cuts through superficial deposits exposing the bedrock in a few places, this is also the area where many of the springs emanate from the underlying sequence.

### 3.4.2. N-S Section through Darlington (Figure 3.13)

The north-south section through Darlington shows similar features to Figure 3.12. The thickest section of the Edlington Formation with gypsum (Hartlepool Anhydrite Formation) has been preserved on the southern flank of the Darlington Syncline (Figure 3.6). The same graben structure shown in Figure 3.12 is intersected, but along this section the faults are farther apart making the graben structure wider. Like the section given in Figure 3.13, the drift deposits are thin along the Tees Valley and the Sherwood Sandstone Group is present at rockhead. The cross-section also shows very thick drift deposits towards the A1 road in the north of the

district (NZ 426520 520420). These thick drift deposits may represent glacial morainic deposits.

### 3.4.3. E-W Section through Darlington (Figure 3.14)

The east-west cross-section through Darlington shows the easterly dip of the strata, also the plunge direction of the Darlington Syncline. Like the other sections, the vertical exaggeration makes the dip/plunge look strong, but in reality, it is probably only 1-2°. This cross-section shows the westward thinning of both the Edlington Formation and the Roxby Formation as the gypsum of the Hartlepool and Billingham Anhydrite Formations has partially dissolved towards the outcrop. This has produced a slight monoclinal structure in the foundered Seaham Formation where it has collapsed across the dissolution front. A similar structure may also exist near the edge of the Sherwood Sandstone Group where it has collapsed over the dissolution front of the Billingham Anhydrite Formation. However, since the Billingham Anhydrite Formation only varies from about 4 to 8m in thickness, it is not very obvious on a cross-section presented at this scale. The other fact that the cross-section shows is the thickness of the drift deposits over most of the area, except where the River Tees runs across the Ford Formation west of Darlington (NZ 423100 514410). Coincidental with this intersection, the Darlington Syncline helps to delineate the Tees Valley, which has exploited the softer strata preserved in the syncline. This coincidence may also have important implications for the local hydrogeology of the Darlington area since the River Tees feeds water into the core of the syncline.

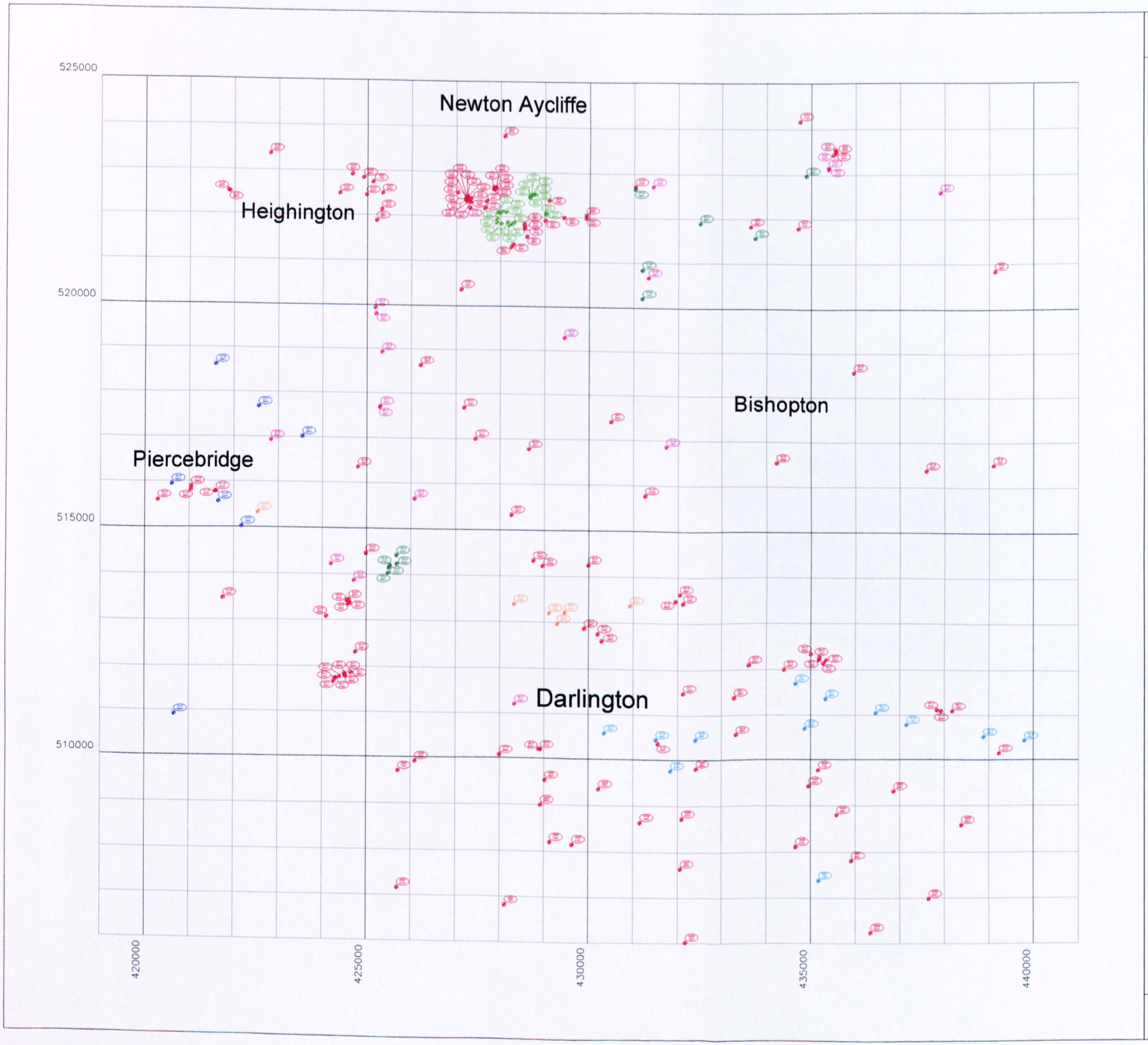



Figure 3.1 - Borehole Locations within Darlington Sub Region Area and their source

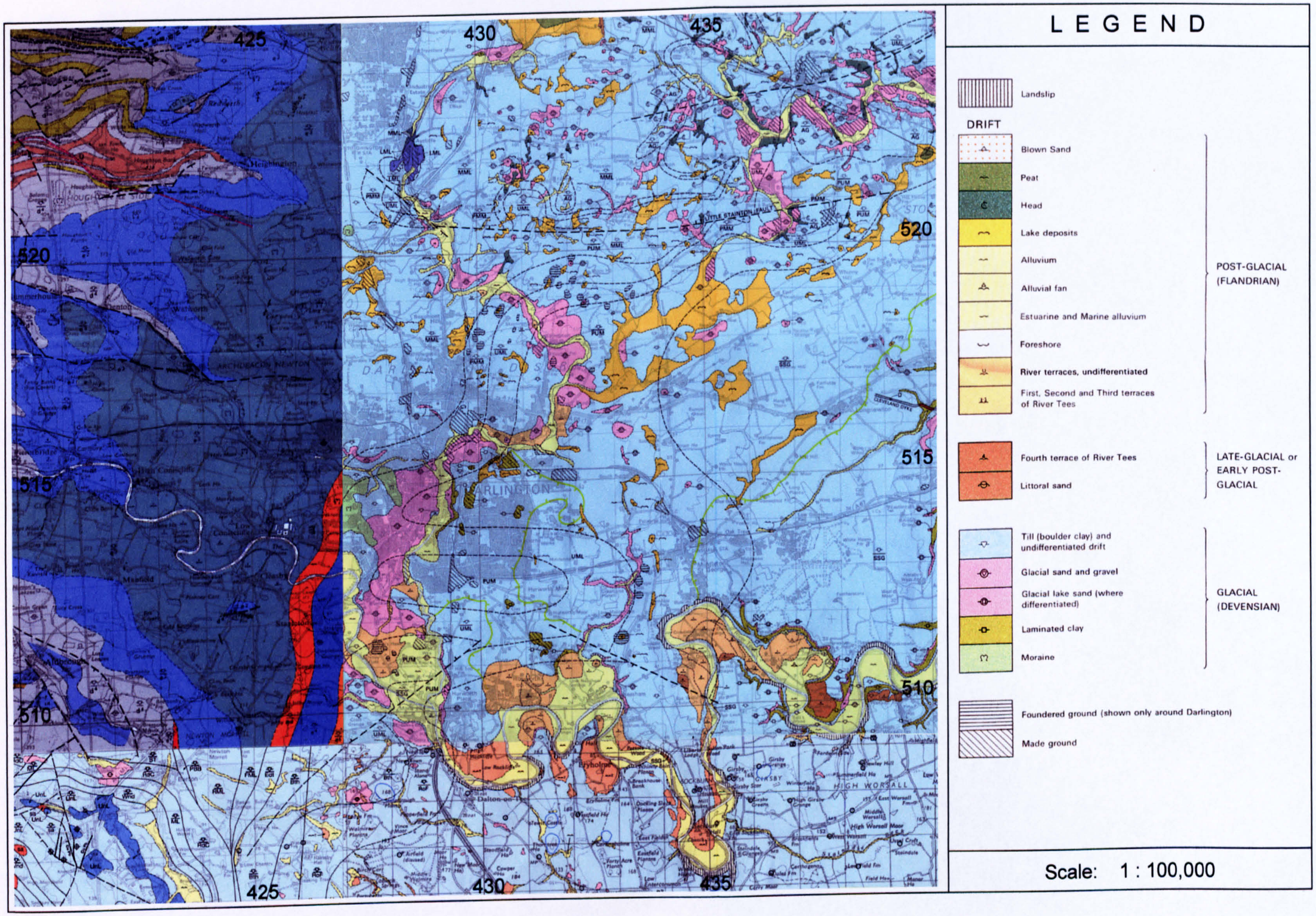
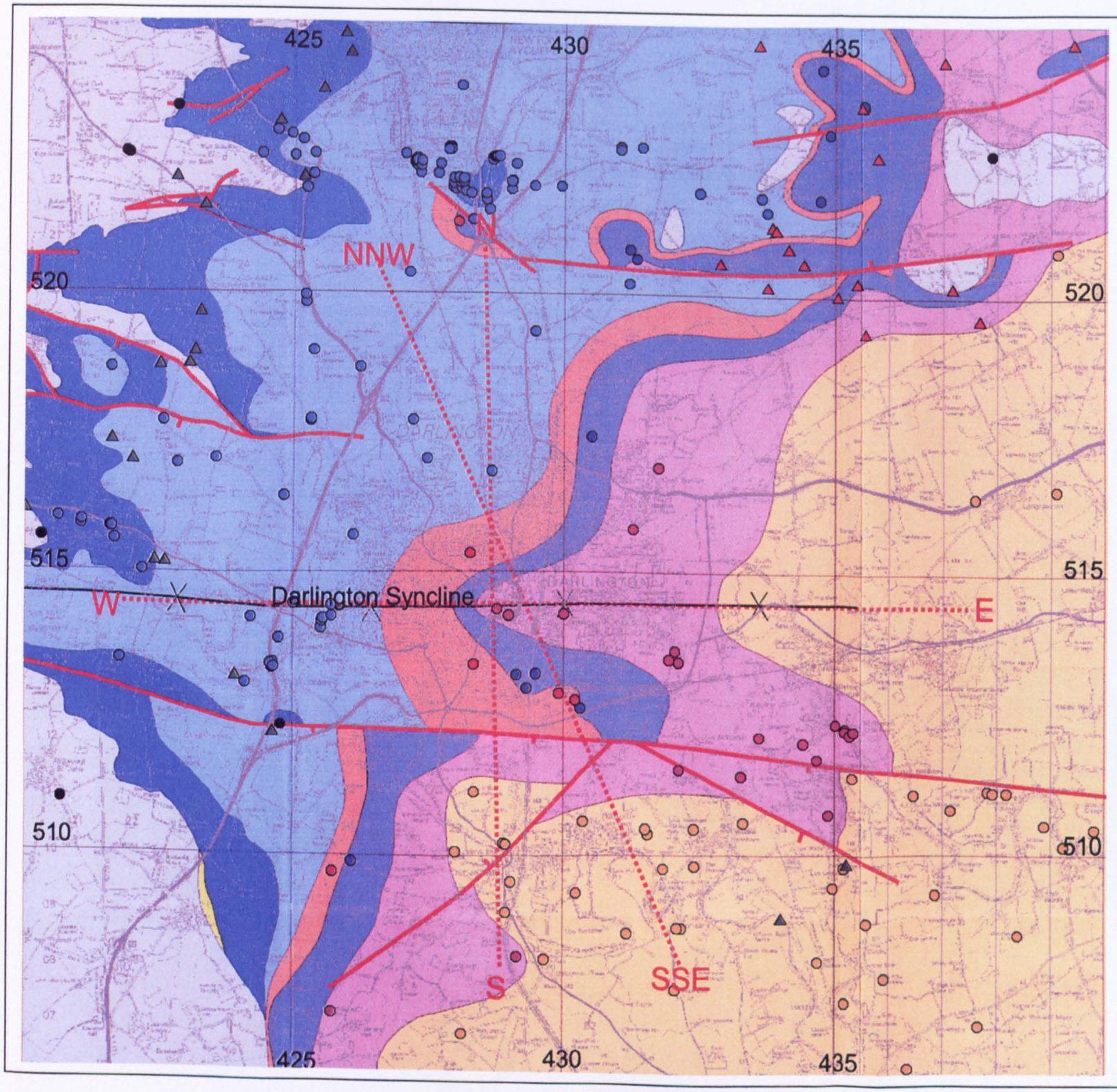



Figure 3.2A - Solid Geology - Extract from Published BGS Map 1987




L E G E N D

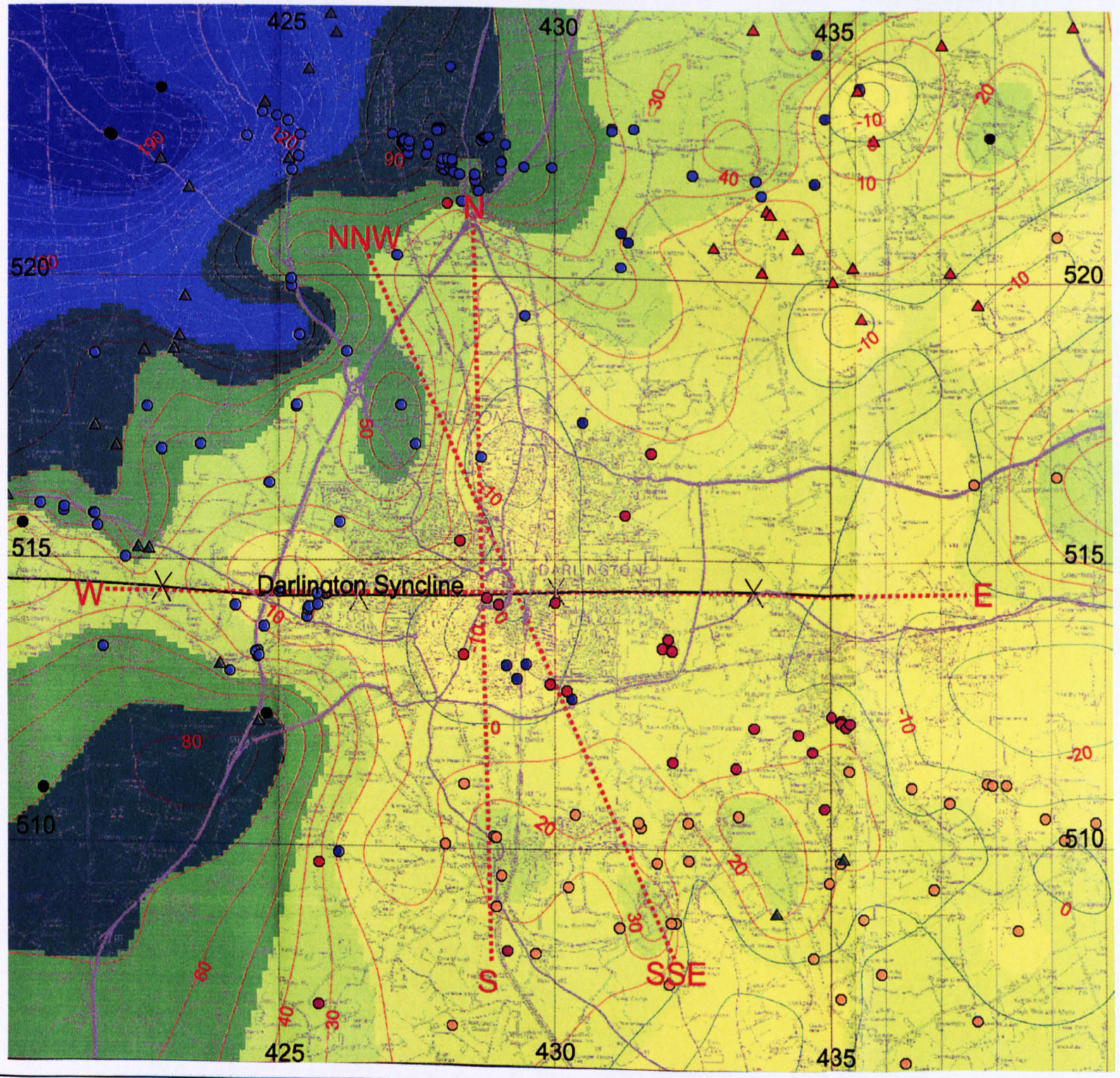
Boreholes, Exposures, Geological Symbols and Colour Codes.

| | |
|---|---|
| Sherwood Sandstone Group | SSG |
| Roxby Formation | ROX |
| Seaham Formation | SEH |
| Edlington Formation | EDT |
| Ford Formation | FML |
| Raisby Formation | RML |
| Basal Permian Sands Formation | |
| Carboniferous Rocks (undifferentiated) | CARB |
| Unnamed Dyke, Tertiary | |

- Exposures of solid rock
- Rockhead proved in BH
- Faults
- Syncline
- Section Lines

Scale: 1 : 100,000

Figure 3.2B - Solid Geology




## L E G E N D

Boreholes, Exposures, Geological Symbols and Colour Codes.

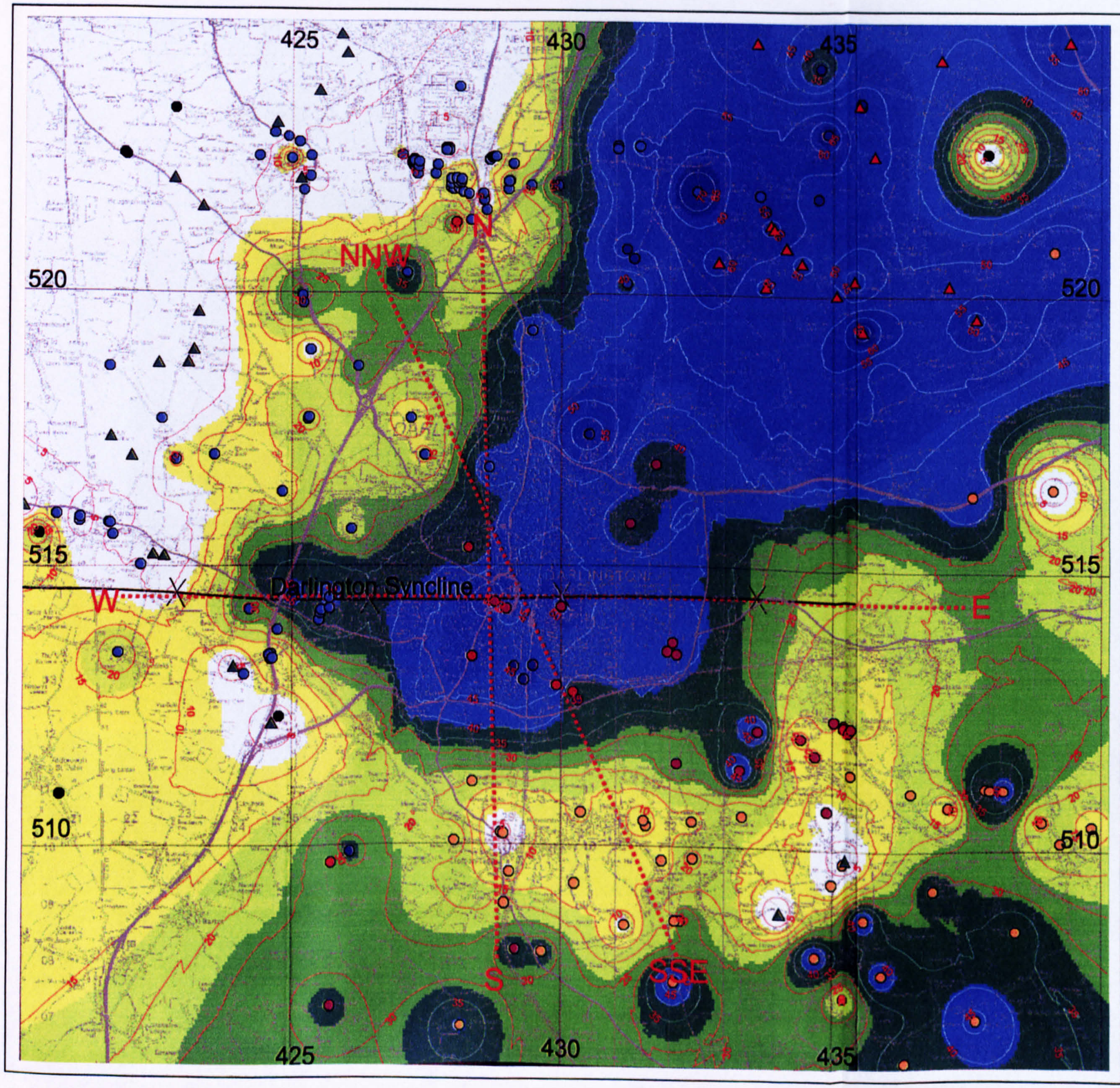
- Sherwood Sandstone Group
- Roxby Formation
- Seaham Formation
- Edlington Formation
- Ford Formation
- Raisby Formation
- Carboniferous Rocks (undifferentiated)
- ▲ Exposures of solid rock
- ▲ Rockhead proved in BH

Contours (m) —— 20 ——

Section Lines .....

Scale: 1 : 100,000

Figure 3.3 - Rockhead Contours




## L E G E N D

Boreholes, Exposures, Geological Symbols and Colour Codes.

- Sherwood Sandstone Group
- Roxby Formation
- Seaham Formation
- Edlington Formation
- Ford Formation
- Raisby Formation
- Carboniferous Rocks (undifferentiated)
- Exposures of solid rock
- Rockhead proved in BH
- Contours (m) — 20
- Syncline
- Section Lines

Scale: 1 : 100,000

Figure 3.4 - Drift Thickness

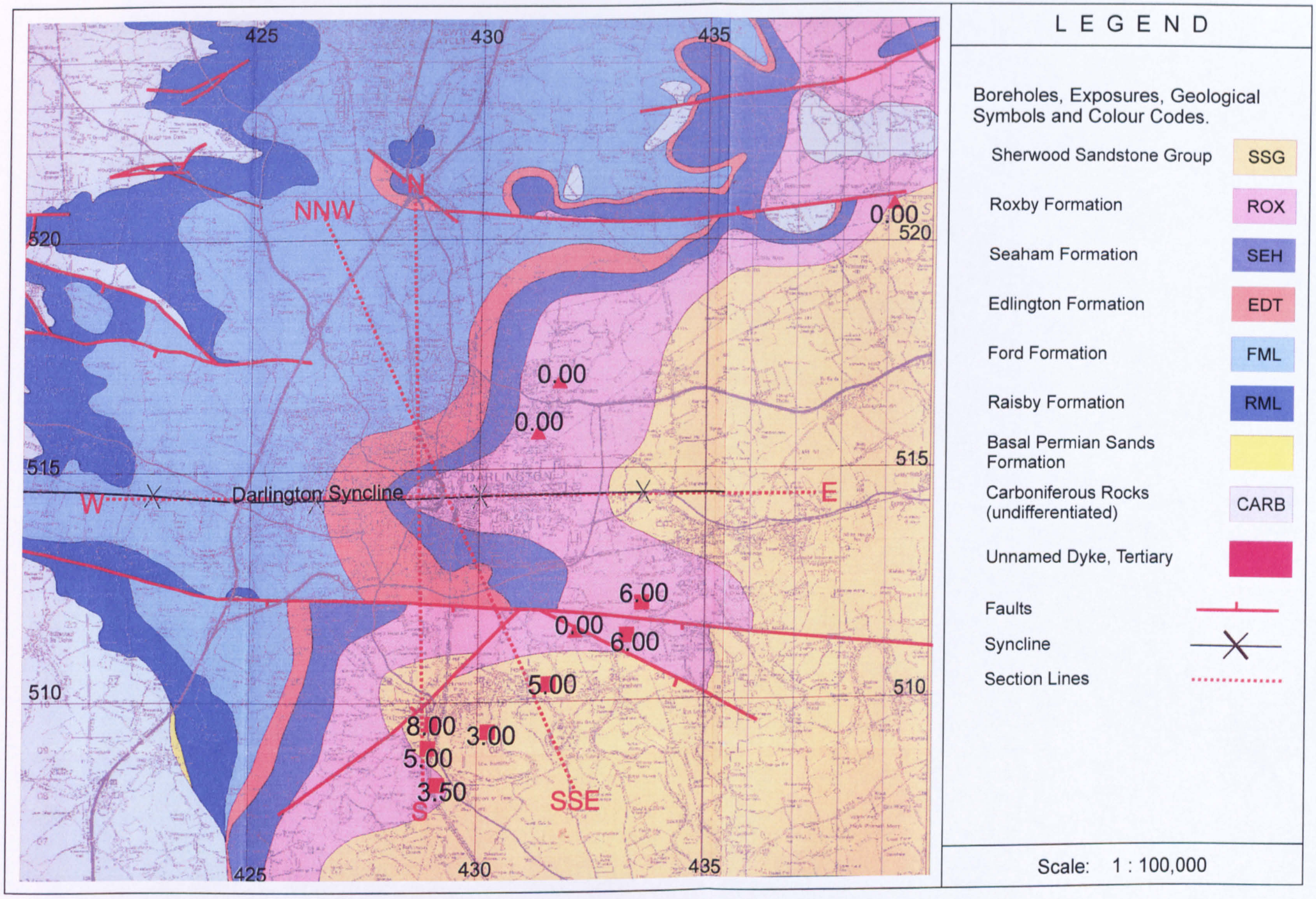



Figure 3.5 - Billingham Anhydrite Fm.

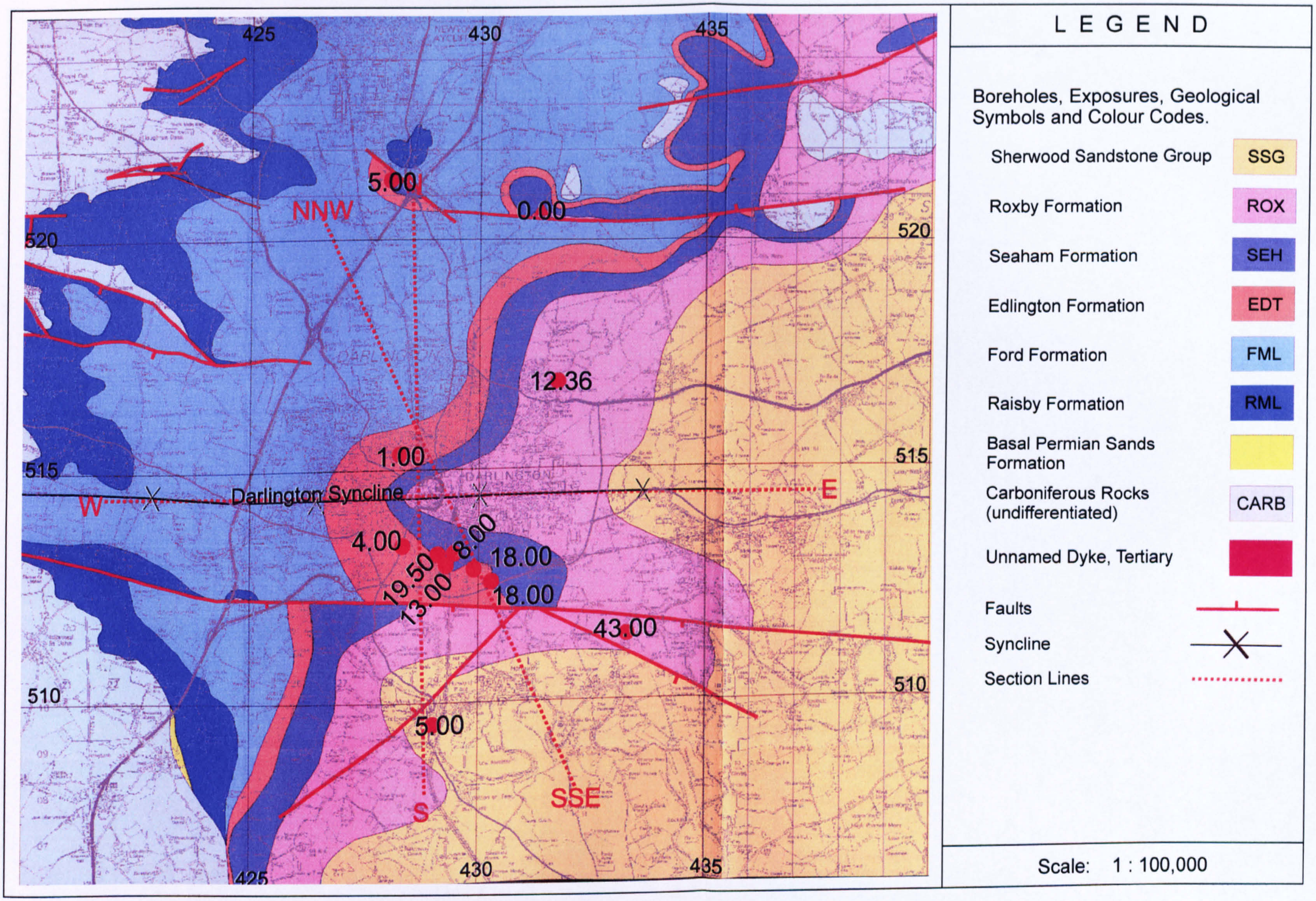
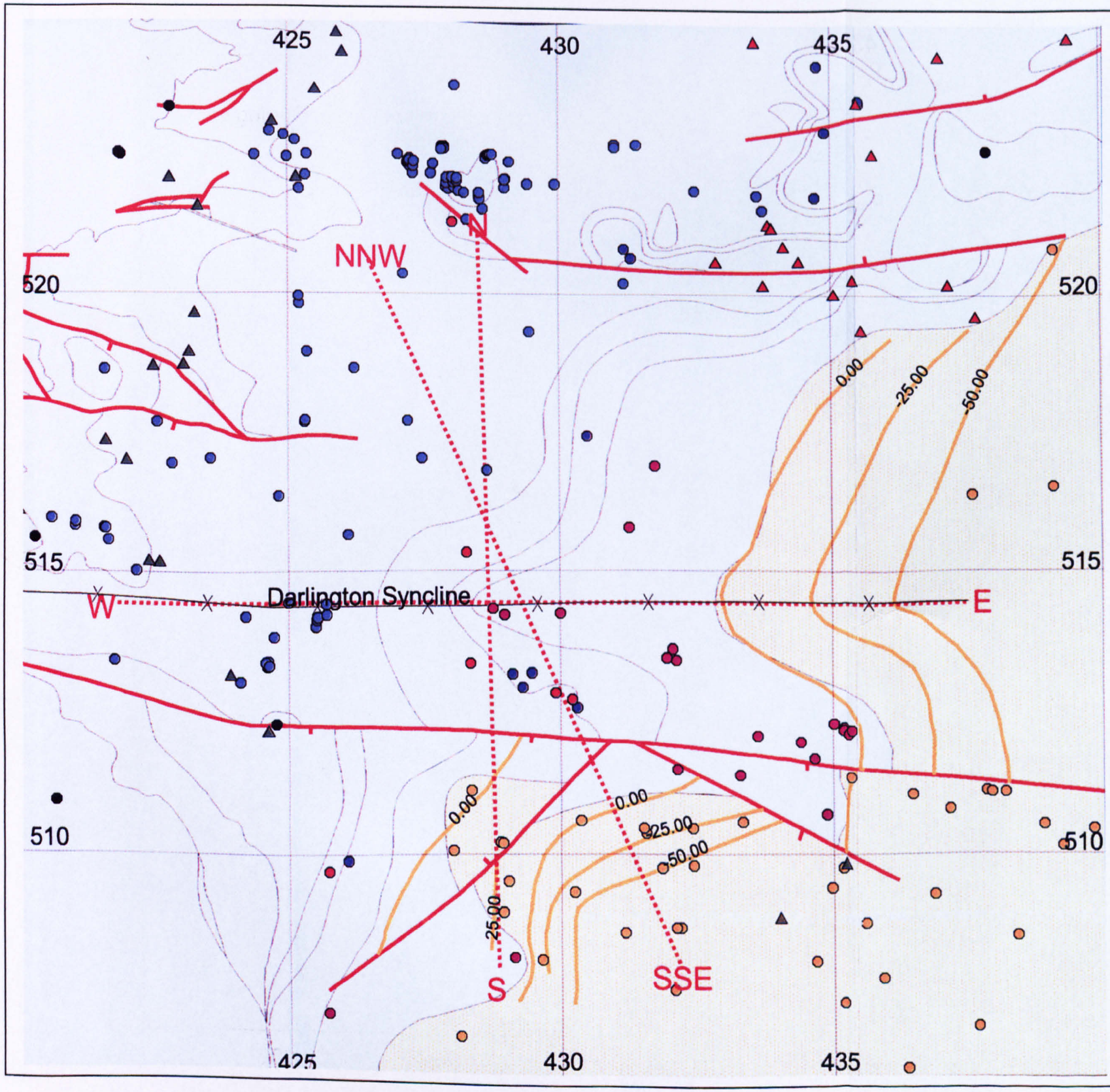



Figure 3.6 - Hartlepool Anhydrite Fm.




## LEGEND

Boreholes, Exposures, Geological Symbols and Colour Codes.

- Sherwood Sandstone Group — SSG
- Roxby Formation
- Seaham Formation
- Edlington Formation
- Ford Formation
- Raisby Formation
- Carboniferous Rocks (undifferentiated)
- Exposures of solid rock
- Rockhead proved in BH
- Structure contours on top of Roxby Formation / base of Sherwood Sandstone Group — -25.00
- Faults
- Syncline
- Section Lines

Scale: 1 : 100,000

Figure 3.7 - Structure Contours
Top Roxby Formation / Base Sherwood Sandstone Group

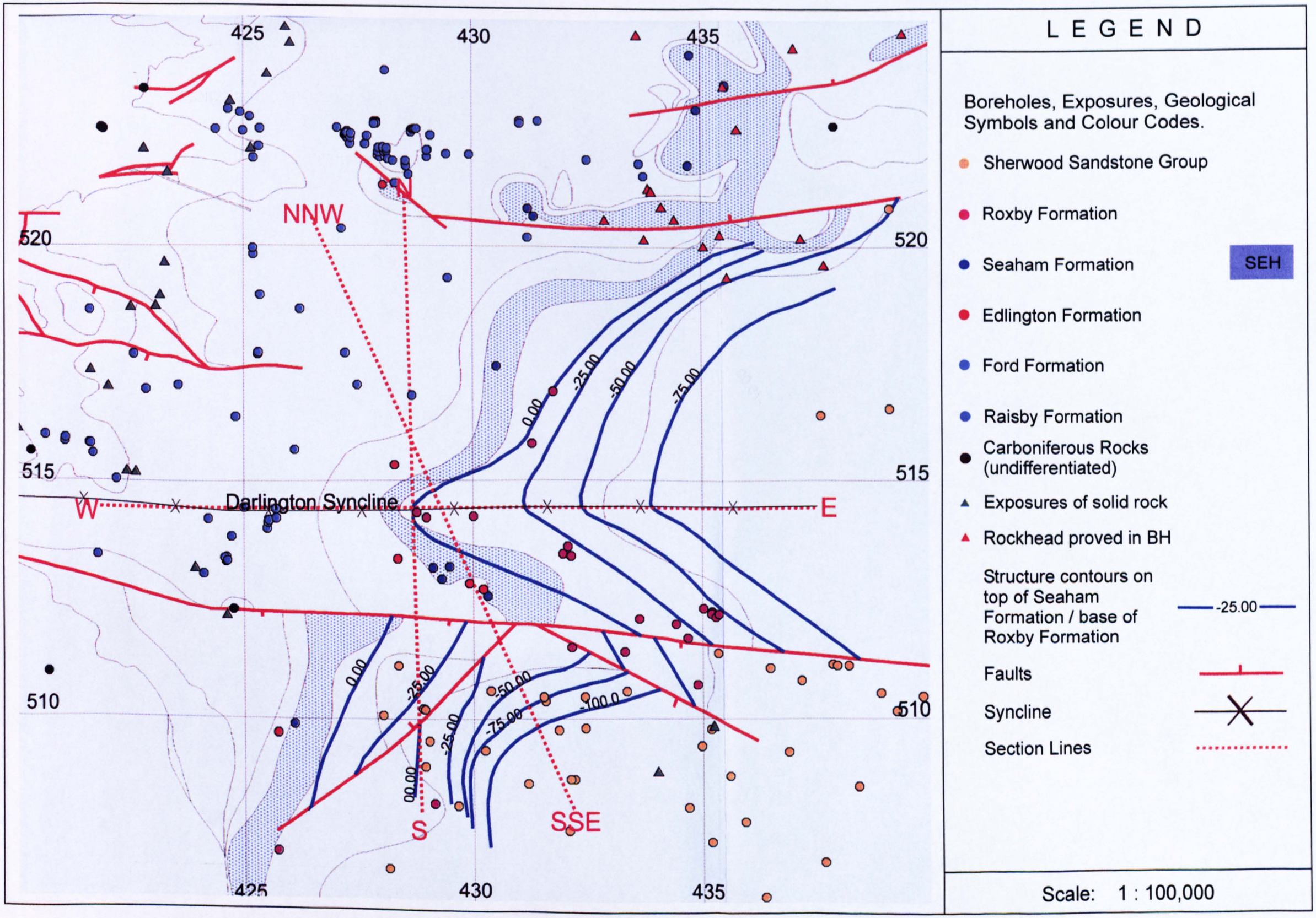



Figure 3.8 - Structure Contours
Top Seaham Formation / Base Of Roxby Formation

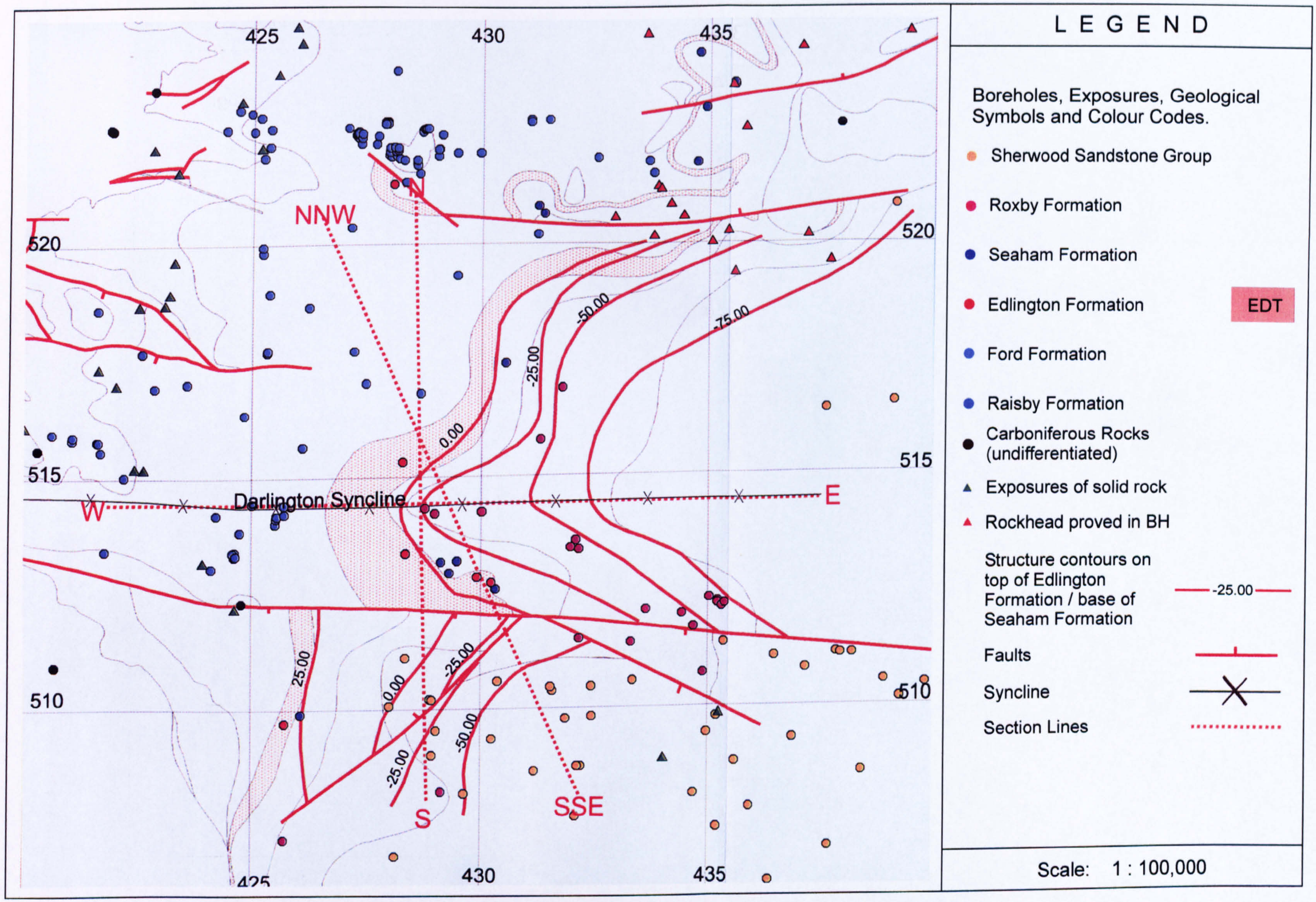



Figure 3.9 - Structure Contours
Top Edlington Formation / Base of Seaham Formation

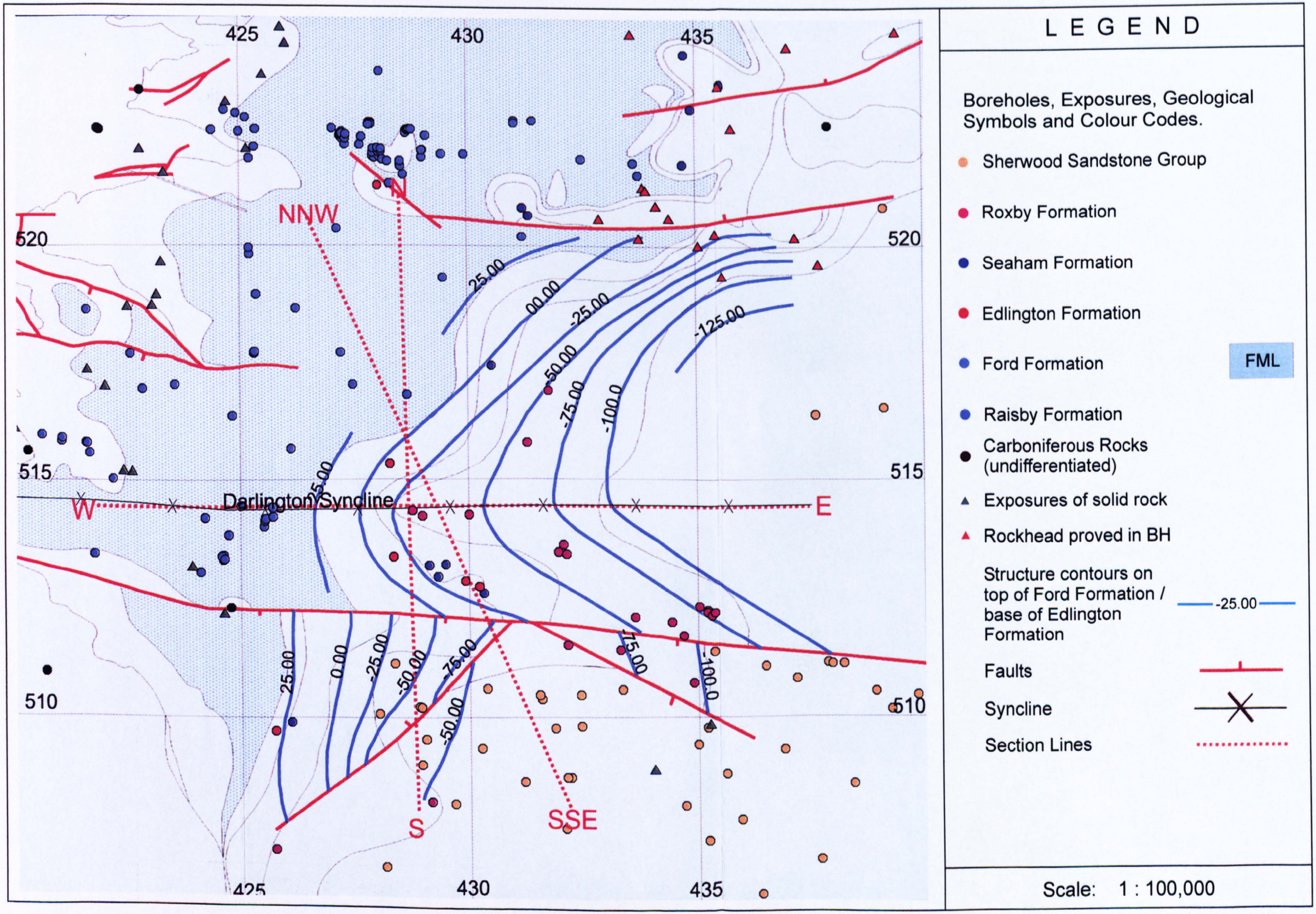



Figure 3.10 - Structure Contours
Top Ford Formation / Base of Edlington Formation

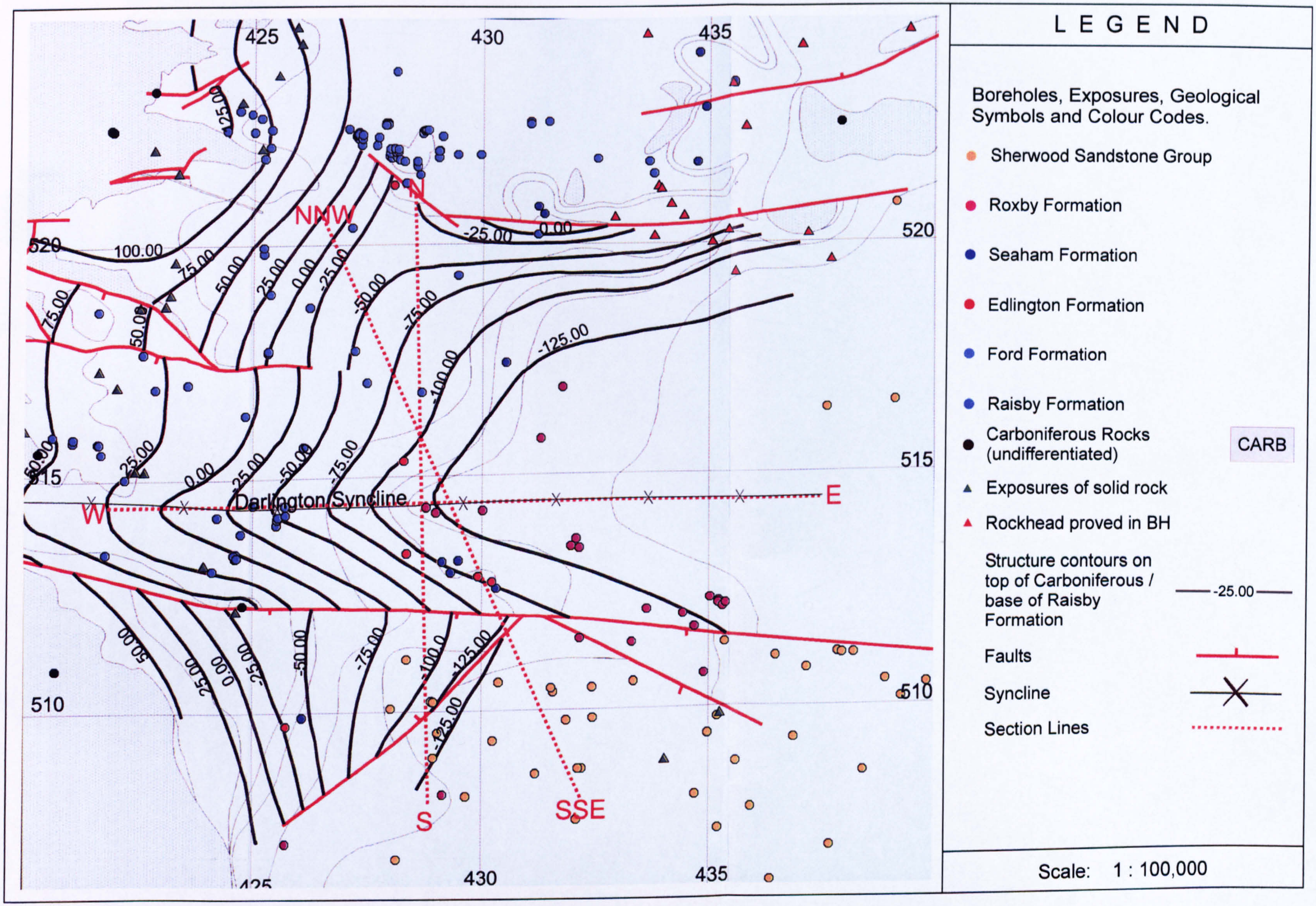



Figure 3.11 - Structure Contours
Top Carboniferous, undivided / Base of Raisby Formation

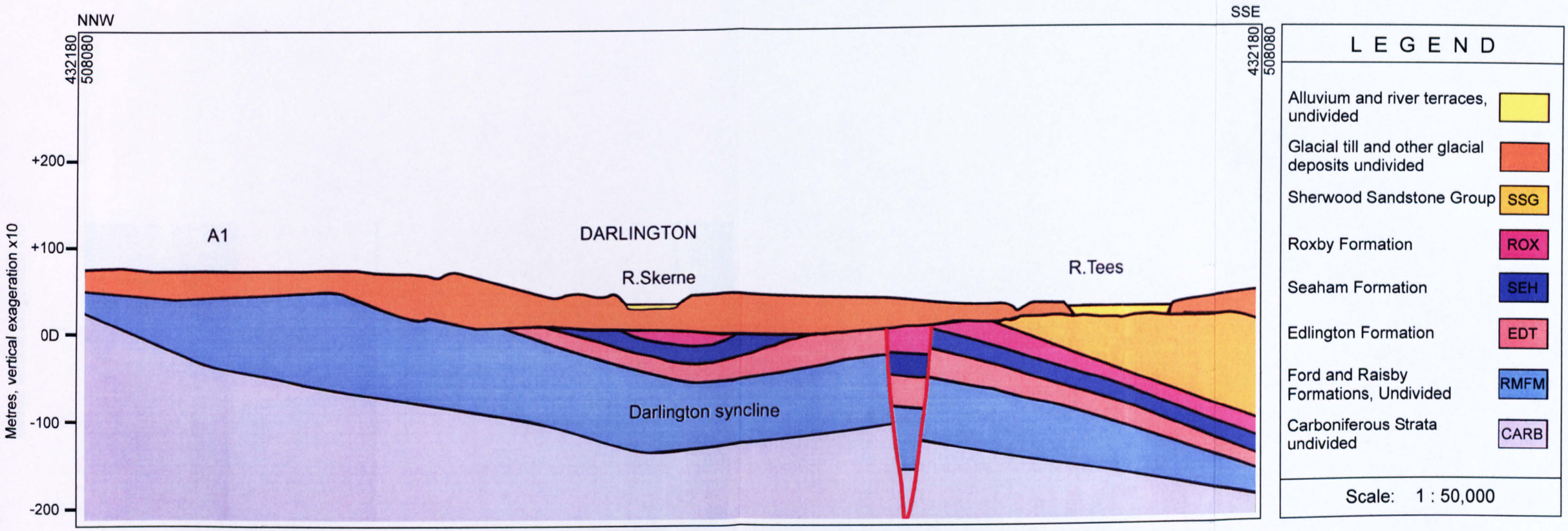



Figure 3.12 - NNW-SSE Section Through Darlington

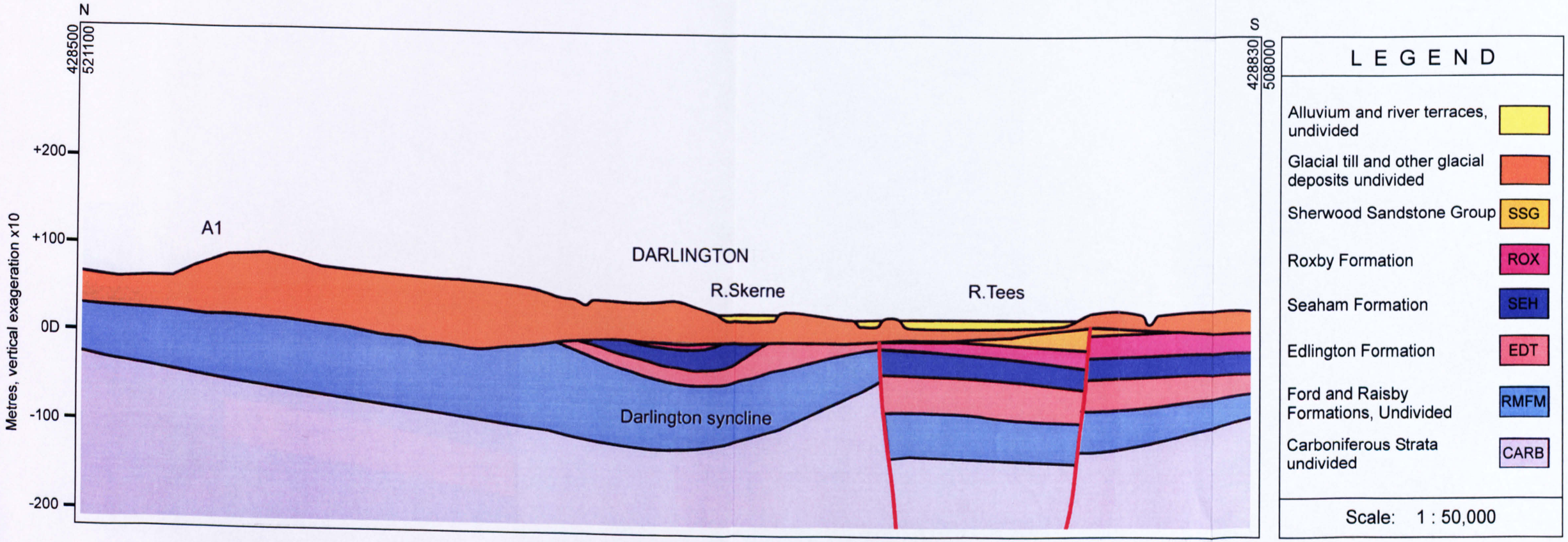



Figure 3.13 - N-S Section Through Darlington

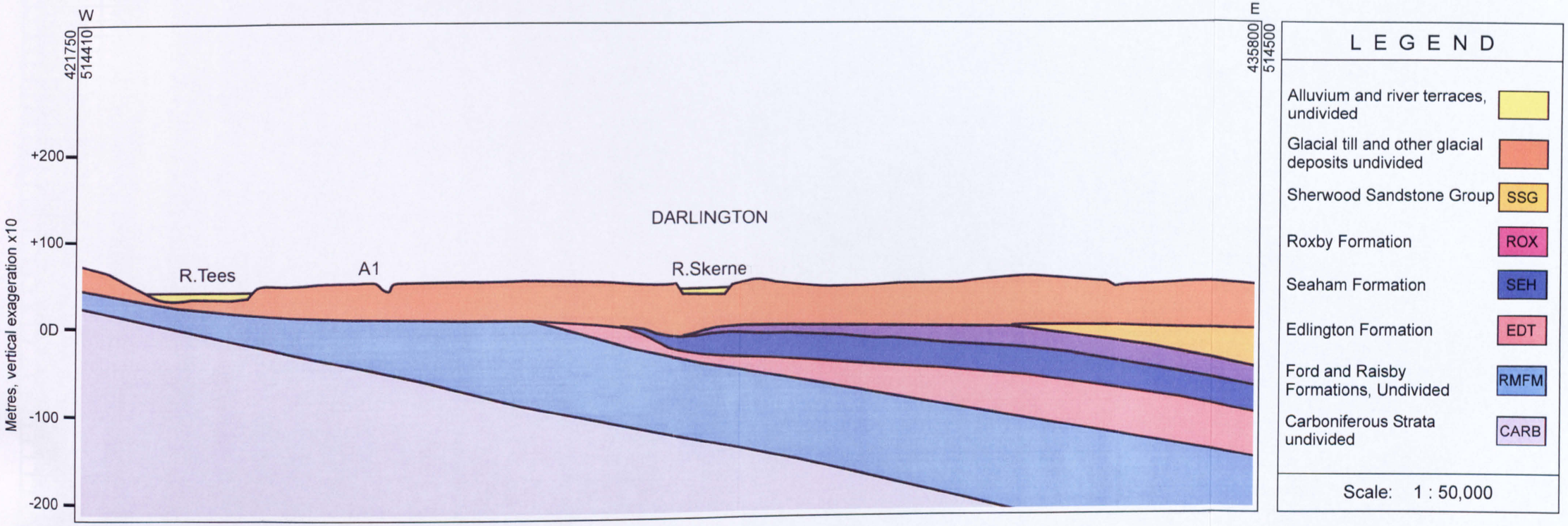



Figure 3.14 - W-E Section Through Darlington

| BH Reference | Easting | Northing | Ground Level | Depth | Drift Thick | Rock Head | Fm at RH | SSG OD | ROX THICK | BILL' H THICK | TOP ROX OD | SEH THICK | TOP SEH OD | EDT THICK | HART THICK | TOP EDT OD | FML THICK | TOP FML OD | RML THICK | TOP RML OD | RMFM THICK | TOP CARB OD | Remarks: tops of units may be truncated by drift |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21137401 | 421760 | 513460 | 77.11 | 43.84 | 23.77 | 53.34 | FML | | | | | | | | | | | | 10.67 | 53.34 | | 42.67 | |
| 24168301 | 424801 | 516347 | 50.29 | 158.80 | 11.58 | 38.71 | FML | | | | | | | | | | | 38.71 | | | 30.84 | 7.87 | |
| 24223401 | 424380 | 522494 | 152.25 | 5.87 | 1.98 | 150.27 | RML | | | | | | | | | | | | 3.13 | 150.27 | | 147.14 | |
| 24229401 | 424980 | 522460 | 140.21 | 33.53 | 26.21 | 114.00 | FML | | | | | | | | | | | 114.00 | | | 5.18 | 108.82 | |
| 25076101 | 425690 | 507160 | 64.62 | 60.96 | 32.00 | 32.62 | ROX | | 11.28 | | 32.62 | | 21.34 | | | | | | | | | | Not very reliable log bh to east proves sequence |
| 25097701 | 425708 | 509706 | 57.91 | 40.23 | 25.30 | 32.61 | EDT | | | | | | | 5.18 | | 32.61 | | 27.43 | | | | | Edlington Formation truncated by drift |
| 26090801 | 426060 | 509890 | 51.82 | 51.21 | 33.12 | 18.70 | SEH | | | | | 12.30 | 18.70 | | | 6.40 | | | | | | | |
| 27201301 | 427120 | 520371 | 77.95 | 84.58 | 36.58 | 41.37 | FML | | | | | | | | | | 8.07 | 41.37 | | 33.30 | | | Carboniferous below -6.63m |
| 28099001 | 428925 | 509003 | 42.12 | 50.90 | 21.34 | 20.78 | SSG | 20.78 | 6.43 | 5.00 | 1.43 | | -5.00 | | | | | | | | | | Billingham 5m gysum/anhydrite |
| 28147302 | 428756 | 514339 | 48.77 | 75.92 | 58.90 | -10.13 | ROX | | 3.17 | | -6.96 | 15.85 | -10.13 | | | -25.98 | | | | | | | Some doubt about Edlington Formation depth |
| 28149205 | 428963 | 514224 | 37.81 | 51.82 | 38.99 | -1.18 | ROX | | 3.38 | | -1.18 | | -4.56 | | | | | | | | | | Pure Ice borehole |
| 28152301 | 428263 | 515328 | 51.81 | 86.50 | 36.00 | 15.81 | EDT | | | | | | | 17.00 | | 15.81 | | -1.19 | | | | | Mem. Hosp. Bh, Red marl + gypsum bands, Edl. Fm. truncated by drift |
| 28166701 | 428650 | 516780 | 29.26 | 86.50 | 41.86 | -12.60 | FML | | | | | | | | | | | -12.60 | | | | | |
| 28210301 | 428032 | 521320 | 83.82 | 110.95 | 35.97 | 47.85 | EDT | | | | | | | 5.18 | 5.00 | 47.85 | 21.33 | 42.67 | 47.86 | 21.34 | 69.19 | -26.52 | Hartlepool 5m gypsum, Edlington Formation truncated |
| 28212301 | 428298 | 521364 | 66.47 | 58.24 | 18.29 | 48.18 | FML | | | | | | | | | | | 48.18 | | | 39.55 | 8.63 | North of fault |
| 29081201 | 429130 | 508200 | 51.05 | 62.58 | 34.75 | 16.30 | ROX | | 23.90 | 3.50 | 16.30 | | -7.60 | | | | | | | | | | Billingham 3.5m gypsum |
| 29086101 | 429632 | 508158 | 51.51 | 76.20 | 33.53 | 17.98 | SSG | 17.98 | | | | | | | | | | | | | | | Roxby Formation top below -24.67 |
| 29149201 | 429989 | 514247 | 47.50 | 74.98 | 50.60 | -3.10 | ROX | | 3.65 | | -3.10 | 15.85 | -6.75 | | | -22.60 | | | | | | | Some doubt about sequence |
| 30092301 | 430230 | 509350 | 32.99 | 129.08 | 13.11 | 19.88 | SSG | 19.88 | 26.39 | 3.00 | -64.85 | | -91.24 | | | | | | | | | | Billingham 3m gypsum |
| 30122607 | 430294 | 512604 | 38.42 | 73.80 | 34.00 | 4.42 | SEH | | | | | 11.90 | 4.42 | 24.53 | 18.00 | -7.48 | | -32.01 | | | | | Hartlepool 18m gypsum |
| 30122702 | 430206 | 512753 | 40.18 | 47.30 | 36.30 | 3.88 | EDT | | | | | | | | | 3.88 | | | | | | | |
| 30175401 | 430500 | 517400 | 64.01 | 76.20 | 58.22 | 5.79 | SEH | | | | | 7.31 | 5.79 | | | -1.52 | | | | | | | ?Seaham Formation or Edlington Formation |
| 31105301 | 431550 | 510360 | 28.60 | 104.32 | 9.75 | 18.85 | SSG | 18.85 | 49.51 | 5.00 | -24.40 | | -73.91 | | | | | | | | | | Billingham 5m gypsum/anhydrite |
| 31139402 | 431942 | 513475 | 48.60 | 42.00 | 40.10 | 8.50 | ROX | | | | 8.50 | | | | | | | | | | | | Sst, possibly founderd Sherwood Sandstone Group or gypsiferous mudst |
| 31152703 | 431270 | 515770 | 45.42 | 54.17 | 37.17 | 8.25 | ROX | | 10.99 | 0.00 | 8.25 | | -2.74 | | | | | | | | | | Billingham dissolved 0m was at 34162504 as well |
| 31220701 | 431030 | 522720 | 92.53 | 91.74 | 49.38 | 43.15 | FML | | | | | | | | | | 20.42 | 43.15 | 14.32 | 22.73 | 34.74 | 8.41 | |
| 32112401 | 432125 | 511490 | 35.66 | 44.68 | 28.96 | 6.70 | ROX | | 12.62 | 0.00 | 6.70 | | -5.92 | | | | | | | | | | Billingham 0m dissolved |
| 33126001 | 433610 | 512100 | 51.21 | 73.61 | 48.21 | 3.00 | ROX | | 25.17 | 6.00 | 3.00 | | -22.17 | | | | | | | | | | Billingham 6m |
| 34217701 | 434710 | 521790 | 64.27 | 109.74 | 51.21 | 13.06 | SEH | | | | | 40.54 | 13.06 | | | -27.48 | | | | | | -41.81 | Edlington Formation with evaporites unconformable on Carboniferous |
| 35235401 | 435550 | 523490 | 38.25 | 73.00 | 51.00 | -12.75 | SEH | | | | | 20.00 | -12.75 | | | -32.75 | | | | | | | |
| 35235501 | 435540 | 523530 | 39.22 | 74.00 | 51.00 | -11.78 | SEH | | | | | 21.00 | -11.78 | | | -32.78 | | | | | | | |
| 27109001 | 427997 | 510070 | 33.50 | 54.40 | 23.47 | 10.03 | SSG | 10.03 | 8.95 | | -7.10 | | -16.05 | | | | | | | | | | |
| 29090501 | 429020 | 509530 | 29.30 | 165.30 | 7.09 | 22.21 | SSG | 22.21 | 26.86 | 8.00 | 10.80 | 13.72 | -16.06 | 7.17 | 5.00 | -29.78 | 70.41 | -36.95 | 13.59 | -107.36 | 84.00 | -120.95 | Breccia -120.57below OD, Billingham 8-16m, Hartlepool 5m |
| 29129801 | 429900 | 512870 | 42.00 | 68.82 | 49.00 | -7.00 | EDT | | | | | | | | 18.00 | -7.00 | | | | | | | Hartlepool 18m+ not bottomed |
| 33112301 | 433280 | 511390 | 54.30 | 132.11 | 46.92 | 7.38 | ROX | | 10.03 | 6.00 | 7.38 | 15.90 | -2.65 | 52.75 | | -18.55 | | -71.30 | | | | | Billingham 6m, Hartlepool 43m |
| 34124001 | 434400 | 512000 | 11.00 | 135.76 | 7.54 | 3.46 | ROX | | 27.97 | | 3.46 | 16.76 | -24.51 | 25.76 | | -41.27 | | -67.03 | | | | | |
| 39201801 | 439130 | 520840 | 44.81 | 100.51 | 53.00 | -8.19 | SSG | | 1.74 | 0.00 | -49.11 | | -50.85 | | | | | | | | | | Billingham dissolved 0m |
| 28133301 | 428331 | 513386 | 38.64 | 101.50 | 49.00 | -10.36 | EDT | | | | | | | 5.00 | 4.00 | -10.36 | | -15.36 | | | | | Hartlepool 4m |
| 29122902 | 429294 | 512967 | 43.61 | 105.00 | 49.15 | -5.54 | SEH | | | | | 14.55 | -5.54 | 18.10 | 13.00 | -20.09 | | -38.19 | | | | | Hartlepool 13m |
| 29131104 | 429108 | 513198 | 40.09 | 93.00 | 44.70 | -4.61 | SEH | | | | | 4.50 | -4.61 | 24.40 | 19.50 | -9.11 | | -33.51 | | | | | Hartlepool 19.5m |
| 29134201 | 429464 | 513214 | 41.48 | 108.00 | 47.50 | -6.02 | SEH | | | | | 0.00 | -6.02 | 40.50 | 8.00 | -6.02 | | -46.52 | | | | | Hartlepool 8m, Seaham Formation foundered |
| 22168901 | 422832 | 516936 | 60.96 | 32.18 | 10.67 | 50.29 | FML | | | | | | | | | | | 50.29 | | | 82.07 | -31.78 | |
| 24141201 | 424192 | 514219 | 51.82 | 78.94 | 31.09 | 20.73 | FML | | | | | | | | | | | 20.73 | | | 44.65 | -23.92 | |
| 25172601 | 425288 | 517675 | 60.05 | 44.20 | 20.72 | 39.33 | FML | | | | | | | | | | | 39.33 | | | | | Carb below 15.87 |
| 25173701 | 425301 | 517709 | 57.91 | 56.92 | 19.82 | 38.09 | FML | | | | | | | | | | | 38.09 | | | 29.76 | 8.33 | |
| 25183901 | 425340 | 518930 | 108.00 | 32.92 | 5.49 | 102.51 | FML | | | | | | | | | | | 102.51 | | | 19.20 | 83.31 | Raisby and Ford formations undifferentiated |
| 25191801 | 425199 | 519807 | 99.21 | 59.82 | 25.91 | 73.30 | FML | | | | | | | | | | | 73.30 | | | 33.91 | 39.39 | |
| 25191901 | 425186 | 519938 | 95.71 | 51.82 | 34.44 | 61.27 | FML | | | | | | | | | | | 61.27 | | | 17.07 | 44.20 | |
| 26150601 | 426080 | 515660 | 48.83 | 39.62 | 21.34 | 27.49 | FML | | | | | | | | | | | 27.49 | | | 16.93 | 10.56 | ?Carboniferous |
| 29194301 | 429450 | 519300 | 56.10 | 61.26 | 41.76 | 14.34 | FML | | | | | | | | | | | 14.34 | | | | | Carboniferous below -5.16 |
| 31167801 | 431741 | 516862 | 45.72 | 125.58 | 36.58 | 9.14 | ROX | | 49.07 | 0.00 | 9.14 | 20.25 | -39.93 | 12.36 | 12.36 | -60.18 | | -72.54 | | | | | Billingham dissolved |
| 31203601 | 431330 | 520670 | 74.40 | 104.24 | 49.38 | 25.02 | SEH | | | | | 19.81 | 25.02 | 6.40 | | 5.21 | | -1.19 | | | | | Hartlepool 0m dissolved, Carboniferous below -29.54 |
| 31224701 | 431433 | 522720 | 89.61 | 78.33 | 57.00 | 32.61 | FML | | | | | | | | | | 18.58 | 32.61 | | 14.03 | | | Carboniferous below 11.28 |
| 25145102 | 425523 | 514195 | 45.72 | 101.19 | 38.40 | 7.32 | FML | | | | | | | | | | | 7.32 | | | 57.69 | -50.37 | |
| 31201201 | 431197 | 520202 | 72.88 | 76.20 | 37.64 | 35.24 | FML | | | | | | | | | | 14.48 | 35.24 | 20.49 | 20.76 | 34.97 | 0.27 | |
| 31201801 | 431198 | 520841 | 83.82 | 126.80 | 52.12 | 31.70 | SEH | | | | | 11.58 | 31.70 | 8.69 | | 20.12 | 31.24 | 11.43 | | -19.81 | | | Carboniferous below -42.98 |
| 31220601 | 431029 | 522668 | 93.57 | 97.54 | 49.38 | 44.19 | FML | | | | | | | | | | | 44.19 | | | 42.67 | 1.52 | |
| 32214801 | 432495 | 521898 | 106.68 | 94.49 | 70.56 | 36.12 | FML | | | | | | | | | | 9.30 | 36.12 | 9.45 | 26.82 | 18.75 | 17.37 | |
| 33217501 | 433744 | 521562 | 71.79 | 79.86 | 54.56 | 17.23 | FML | | | | | | | | | | 11.91 | 17.23 | | 5.32 | | | Carboniferous below -8.07 |
| 34228901 | 434894 | 522982 | 69.10 | 74.98 | 66.45 | 2.65 | SEH | | | | | 11.58 | 19.42 | 5.19 | | 7.84 | | 2.65 | | | | | Carboniferous below -5.88 |

Table 3.2 Key boreholes with thickness information in the Darlington area

Abbreviations:
SSG: Sherwood Sandstone Group; ROX: Roxby Formation; SEH: Seaham Formation; EDT: Edlington Formation; FML: Ford Formation; RML: Raisby Formation; RMFM:Raisby and Ford Formations, undivided; CARB: Carbonifeous, undivided

## 3.5. Drift Geology

In almost all the Darlington sub region study area, the Permo-Triassic strata are concealed beneath Quaternary drift and Holocene deposits of varying ages. Information gathered from 1029 boreholes, which either terminated within the drift or penetrated the drift/solid geology was used to compile new geological interpretations.

The drift geology was considered within the three scoping areas. The number of boreholes associated with each area and the appropriate location plan are shown in Table 3.3.

| Scoping Area | No of BHs | Location Plan |
|---|---|---|
| Sub region | 240 | Figure 3.1 |
| Town Centre | 335 | Figure 3.15 |
| River Corridor | 454 | Figure 3.18 |

Table 3.3 - Number of Boreholes within Scoping Areas

A comprehensive list of borehole data is given in Appendices 3.1, 3.2 and 3.3.

## 3.6. Drift Thickness

The map of drift thickness (Figure 3.4) complements that of the rockhead contour map. Where the Raisby and Ford Formations form the high ground in the north-west part of the area the drift is thin, generally less than 5m thick. In the low ground over the north-eastern quarter of the district extending into the area of Darlington itself the drift is thick, ranging from 40 to 60 metres. The exception is at the location of one borehole near the north-east of the map, where the drift thickness is shown to be around 10m. This may be an artefact caused by an incorrectly interpreted borehole, or it might represent a buried hill of Carboniferous strata that penetrates through the Permian cover and is still exposed at rockhead beneath the drift. This latter explanation is suggested by the interpretation of the borehole by Smith (1987) when the Stockton Geological map was published.

No attempt has been made to revise the drift geology of the sub region area; reference should be made to the published 1:50,000 scale geological map (British Geological Survey, 1987). The boreholes that penetrated the solid strata generally agreed with the geological map for the drift geology of the area. The thick drift over the district is mainly glacial till (formerly called boulder clay). Some thick glacial till is present to the west and north of Darlington, some of this is mapped as glacial moraine and other places such as High Beaumont Hill Farm (NZ 4298 5193) may also be morainic features. Laminated clay is present in the sequence forming an easterly widening belt extending from Darlington along the Tees valley to Middlesbrough and Billingham. Throughout most of this area the laminated clay is both overlain and underlain by glacial till. Patchy glacial sand and gravel is also associated with the till. River terraces are present along the course of the River Tees and alluvial deposits are associated with both the rivers Skerne and Tees.

### 3.7. Town Centre Area

A more detailed analysis of the drift overlying the town centre area was possible because of the greater concentration of borehole information. The details of the drift structure are shown in the two cross sections derived from the town centre geology dataset:

- Figure 3.16 E-W Section through Darlington Town Centre
- Figure 3.17 N-S Section through Darlington Town Centre

Both cross sections were constructed with a horizontal scale of 1:4000 and a 10-times vertical scale of 1:400. This exaggerated scale allowed greater distinction between individual sediment units.

The two sections shown are representative of other parallel sections within the area and indicate a minimum of six major components within the drift (Table 3.4):

| Level | Sequence | Depth (m) min | Block | Depth (m) max |
|---|---|---|---|---|
| 6 | Made Ground | 0.5 | Various | 2.5 |
| 5 | Alluvial sediments restricted to flood plain | 1 | Sands<br>Gravels<br>Silts | 3 |
| 4 | Glacio-fluvial outwash sediments or<br>Postglacial river terrace | 4 | Sand<br>Gravel<br>Cobbles | 15 |
| 3 | Glacial till<br>Silty Clays | 5 | Silty<br>Clays | 16 |
| 2 | Glacio-fluvial outwash sediments grading to<br>Glacio-lacustrine silts and clays | 7 | Sands<br>Silts<br>Clay | 25 |
| 1 | Glacial Till<br>Boulder Clay/Silty Clay | 10 | Clays | 26 |
| 0 | Rockhead | - | Solid | - |

Figure 3.4 - Generalised Drift Sequence, Town Centre
(based on E-W Section)

Both cross sections complement each other and confirm a broad consistency of stratigraphy with the drift by identifying the six major components.

### 3.7.1. Level Zone - Rockhead

In the east-west cross section (Figure 3.16) the rockhead is irregular, varying from -10m (AOD) beneath the Skinnergate area and +5m (AOD) in the Market Place area, situated between Tubwell Row and St Cuthbert's Church. A general north to south dip of about one degree (1°) is indicated by Figure 3.3.

### 3.7.2. Level One - Glacial Till

The section shows a significant layer of glacial till, ranging between 10m to 26m in thickness. Two main types of sediment are shown within the layer, boulder clay and silty clay, hence the notional boundary comprising dotted lines is suggested; however limited evidence from the borehole information is available in this regard.

This predominant drift type overlays the study area and was laid down by the Stainmore ice sheet during the Dimlington Stadial Glaciation of the Late Devensian period. The clay was extensively fissured and charged with numerous boulders of Shap Granite and yellow sandstone, particularly on the eastern part of the area.

### 3.7.3. Level Two - Fluvio-glacial Outwash Sediments

Glacial sands and gravels represent water-lain sediments deposited within pro-glacial, subglacial or englacial environments. This marginal glacial activity has resulted in a fairly uniform layer of sediment grading from silts, sands through to coarse sand and gravel. The thickness of the fluvio-glacial sediment varies from about 7m to 25m. An isolated tongue of sandy silt is also shown on this cross section, but this is probably an artefact and is actually part of this main layer. A wide, thin unit of clay is wedged within the main layer; this is interpreted as deposition of fine grained muds associated with the stagnation of the ice sheet. This clay layer was recorded in several boreholes with perched water tables.

### 3.7.4. Level Three - Glacial Till

This deposit is probably associated with the renewed advance of Devensian ice and is similar in nature to that described in Level One. However, considerable erosion and interaction at the interface with overlying soils has occurred. Generally the clays are less coarse grained, well laminated and with a high silt content. This layer is more variable in thickness and shape. Borehole data indicate erratic rock inclusions varying in thickness from 5m and 16m.

### 3.7.5. Levels Four & Five

These sediments indicate a complex depositional situation. The main sediment layer is likely to be the fluvio-glacial outwash sediments laid down by the melt

waters during the final retreat phase of the Late Devensian glaciers. These sediments typically occur on the sides of the main river, above the limits of the postglacial river terraces. Alternatively this layer may represent river terrace construction since there is an absence of clay content. This layer varies from 4m to 6m in thickness. Again, as was the case in the Level Two layer, these are geographically extensive but a wide thin unit of clay is interbedded with the outwash sediments. This layer was subsequently cut through by the postglacial river terraces across a broad River Skerne floodplain, which extends to about 410m in width. Within the flood plain corridor, alluvial sediments are recorded beneath the contemporary flood plain of the river, these are the most recently formed drift deposits. Typically comprising a basal unit, also sand and gravels which also contain finer silts. It is difficult to give a definitive thickness of the overall river terrace deposits but it would appear that they are about 4.5m to 6m in thickness. Furthermore, there is a general uniformity and symmetry to the wide flood plain and its sedimentary deposits.

### 3.7.6. Level Six - Made Ground

The made ground generally thickens towards the river from about 0.5m to 2.5m; however, much of the present day profile has been extensively engineered and regraded thereby distorting the natural profile. The made ground is an admixture which includes modern debris arising from adjacent building operations.

Mills & Halliday (1976) made reference to a similar drift sequence comprising at least six layers of granular and cohesive material in the River Derwent Valley, situated north-north-east of Edmundbyers.

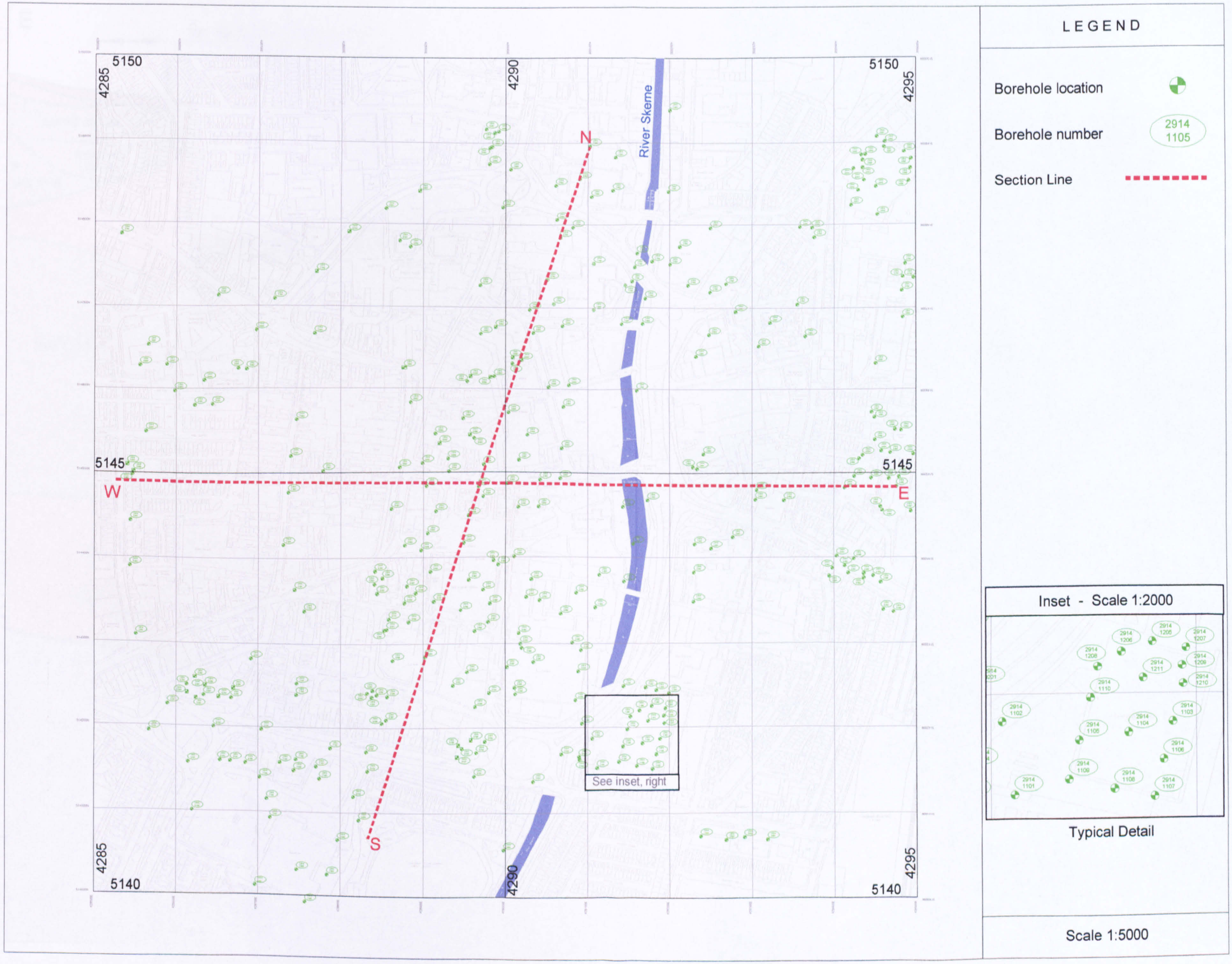



Figure 3.15 - Borehole Locations Within Town Centre Area

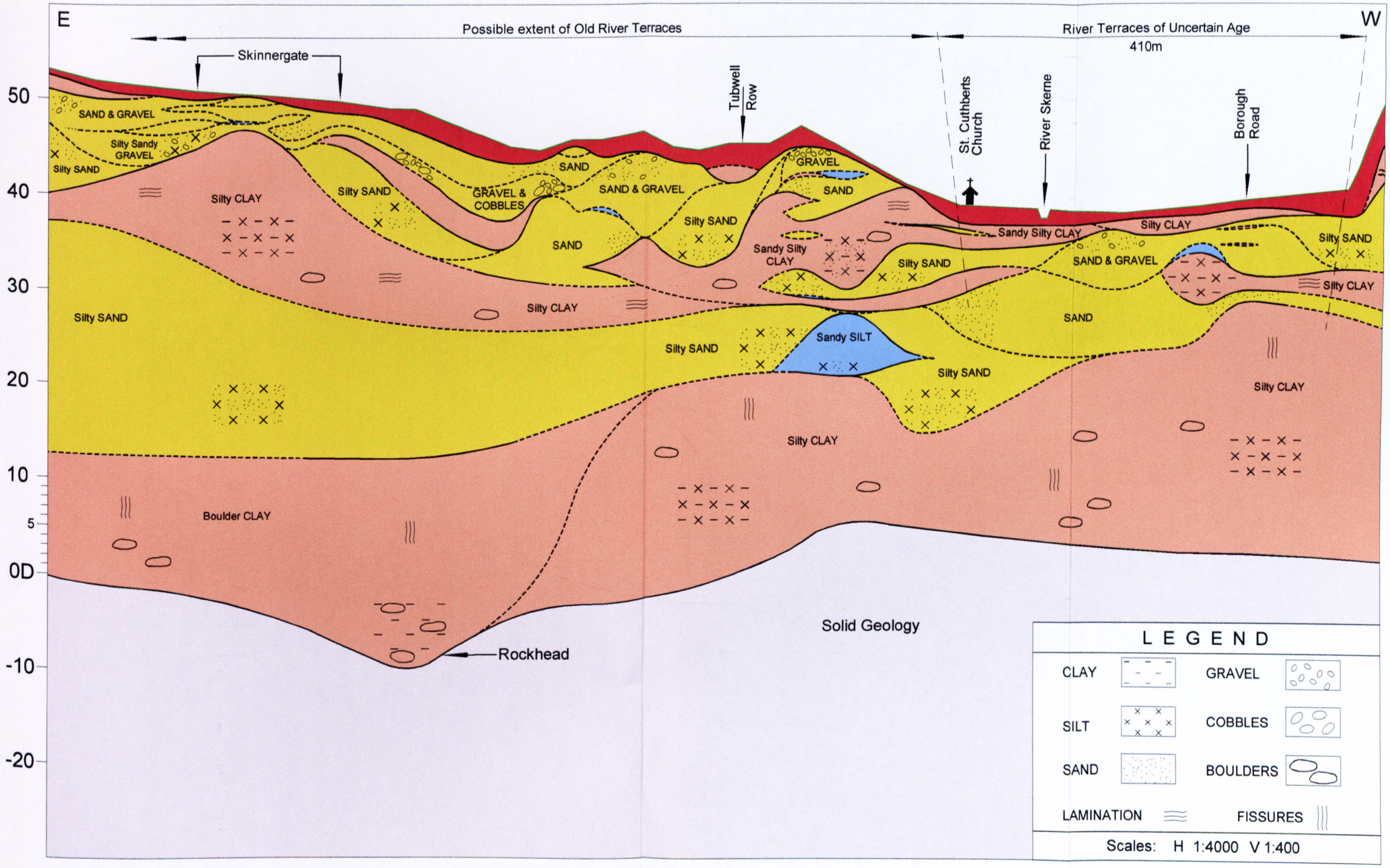



Figure 3.16 - E-W Section through Darlington Town Centre Area

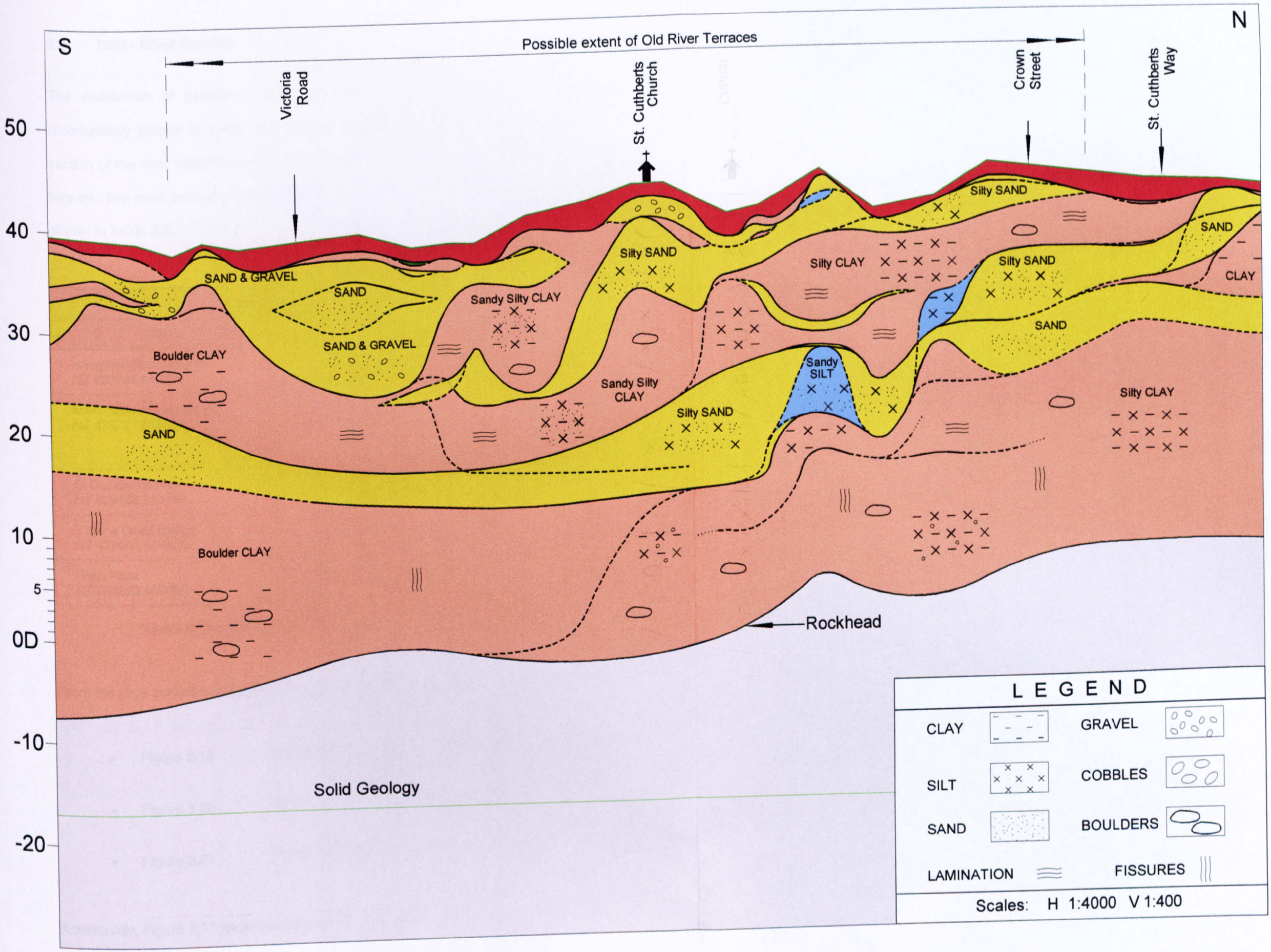



Figure 3.17 - N-S Section through Darlington Town Centre Area

## 3.8. Drift - River Corridor

The distribution of geological data, resulting from the 454 boreholes recorded, is unfortunately patchy in places and does not permit a reliable continuous longitudinal section of the river valley deposits to be constructed. The information collected naturally falls into five main sections of the river from the Tees to Great Burdon Bridge - these are shown in Table 3.5.

| Location | | Coverage | Figure |
|---|---|---|---|
| From | To | | |
| Haughton Road Bridge<br>NZ 430748 515757 | Great Burdon Bridge<br>NZ 431643 516454 | Poor | N/a |
| Main Railway Line Bridge<br>NZ 429727 516071 | Haughton Road Bridge<br>NZ 430748 515757 | Good | 3.18<br>3.19<br>3.20<br>3.21 |
| St Cuthbert's Way<br>NZ 429166 514743 | Main Railway Line Bridge<br>NZ 429727 516071 | Poor | N/a |
| Victoria Road Bridge<br>NZ 429054 514128 | St Cuthbert's Way<br>NZ 429166 514743 | Good | 3.15<br>3.17 |
| River Tees<br>NZ 428923 510092 | Victoria Road Bridge<br>NZ 429054 514128 | Patchy | N/a |

Table 3.5 - Distribution of Borehole Data within the River Skerne Valley

From the data available a series of new geological drawings was constructed, these are:

- Figure 3.19 Longitudinal Section, North Bank of the River Skerne.
- Figure 3.20 Cross Section A-A of the River Skerne Valley.
- Figure 3.21 Cross Section B-B of the River Skerne Valley.

Additionally, Figure 3.17 gives a cross section through Darlington town centre.

The drawings generally verify the strata indicated by the published geological map. The soils encountered can be basically grouped as follows:

- Alluvium consisting of silty clays, organic clays, sand and gravel.
- Geological deposits consisting of laminated clays, boulder clays and pockets of sands and gravels.

Topsoil was encountered throughout the river valley, except within the built-up areas. The predominant feature of the river valley is the extent of made ground, much of which is contaminated. The position of the recorded water table at the various times of drilling is shown on the longitudinal sections as an indicative level. Generally standing water level ranged from about 0.45m to 1.20m below ground level with an overall average of about 0.70m. The majority of these observations were made during the summer months of 1968.

Remnants of peat deposits were encountered throughout the river corridor. Of those recorded the average bed thickness was about 1.40m. Often the peat was interbedded within the sands, gravels, silts and clays. The general distribution of known peat deposits is given in Figure 3.19. Within the town centre area peat deposits lie within the limits of the wide river terrace as shown on Figure 3.16. Between the Main Railway Line bridge and Haughton Road Bridge, two distinct thin layers of peat are shown approximately 2.0 m apart as measured in the vertical plane, both of which are below the recorded summer water table. The instance of peat presence is given in Table 3.7.

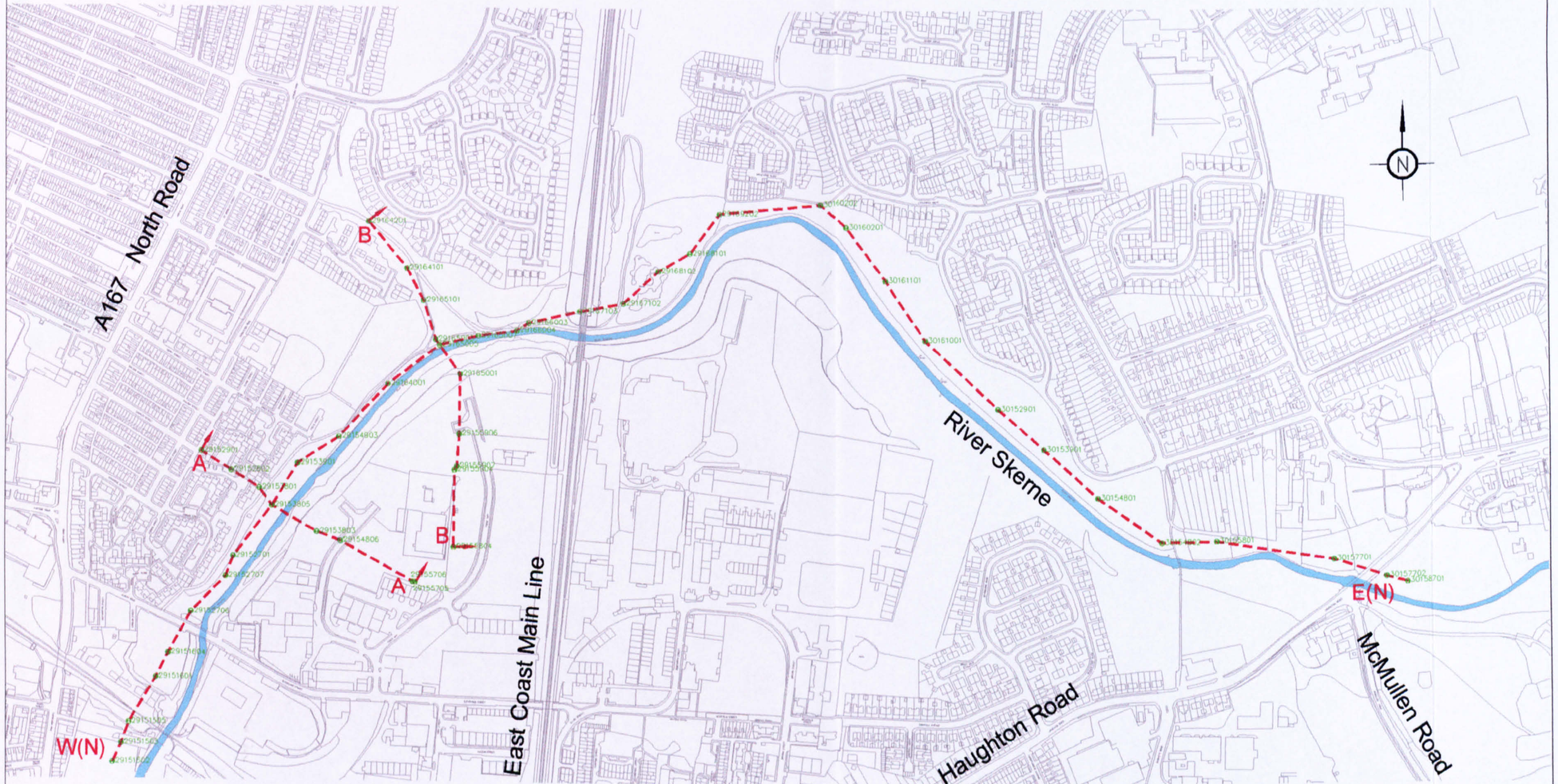
| Borehole No | Approx Thickness (m) | NGR | |
|---|---|---|---|
| | | Easting | Northing |
| 2814·9205 | 0.36 | 428963 | 514224 |
| 2914· 0205 | 1.00 | 429178 | 514225 |
| 2914· 1103 | 1.01 | 429188 | 514186 |
| 2914· 1104 | 1.20 | 429167 | 514181 |
| 2914· 1202 | 0.30 | 429171 | 514247 |
| 2914· 1203 | 0.10 | 429184 | 514243 |
| 2914· 1204 | 0.80 | 429199 | 514240 |
| 2914· 1205 | 0.30 | 429178 | 514225 |
| 2914· 1206 | 0.60 | 429163 | 514220 |
| 2914· 1208 | 0.70 | 429152 | 514213 |
| 2914· 2301 | 0.76 | 429229 | 514382 |
| 2914· 2403 | 0.20 | 429276 | 514424 |

Table 3.6 - Distribution of known Peat Deposits within the Town Centre Area

The distribution of peat deposits outside of the town centre area is given in Table 3.7:

| Borehole Number | Approx Thickness (m) | NGR | | Depth (m) |
|---|---|---|---|---|
| | | Easting | Northing | |
| k2811 9301 | 2.40 | 428942·0 | 511385·0 | 2.70 |
| 2812 4904 | 0.80 | 428427·7 | 512947·0 | 2.70 |
| 2915 1402 | 2.44 | 429117·0 | 515471·5 | 0.76 |
| 2915 3805 | 1.22 | 429318·5 | 515855·5 | 0.30 |
| 2915 4902 | 2.80 | 429463·5 | 515930·0 | 12.20 |
| 2915 5905 | 1.90 | 429515·0 | 515958·0 | 14.50 |
| 2916 4001 | 1.52 | 429471·5 | 516010·5 | 0.30 |
| 2916 5002 | 1.75 | 429548·5 | 516005·5 | 12.00 |
| 2916 5003 | 2.44 | 429534·0 | 516067·0 | 0.61 |
| 2916 5005 | 0.61 | 429539·5 | 516060·0 | 3.05 |
| 2916 5006 | 2.44 | 429542·0 | 516071·0 | 1.52 |
| 2916 5007 | 1.21 | 429590·5 | 516071·5 | 2.29 |
| 2916 5101 | 2.13 | 429518·5 | 516117·5 | 2.13 |
| 2916 7102 | 0.92 | 429781·5 | 516115·0 | 0.30 |
| 2916 8101 | 1.22 | 429869·5 | 516180·5 | 0.30 |
| 2916 8102 | 1.37 | 429828·0 | 516157·2 | At surface |
| 2916 9202 | 0.46 | 429908·0 | 516233·0 | At surface |
| 2916 9205 | 0.80 | 429964·0 | 516210·0 | 2.70 |
| 3015 2901 | 3.36 | 430275·0 | 515980·5 | 0.30 |
| 3015 2902 | 0.30 | 430240·5 | 515957·0 | 1.52 |
| 3015 2903 | 0.31 | 430272·0 | 515908·0 | 1.37 |
| 3015 2905 | 1.00 | 430233·0 | 515960·0 | 2.50 |
| 3015 4801 | 1.38 | 430406·5 | 515868·5 | 0.30 |
| 3015 7702 | 1.98 | 430786·0 | 515767·0 | 3.35 |
| 3016 0104 | 0.40 | 430002·0 | 516192·0 | 3.20 |
| 3016 0201 | 1.22 | 430076·0 | 516215·5 | 2.74 |
| 3016 0202 | 0.46 | 430040·5 | 516247·0 | At surface |
| 3016 1001 | 1.06 | 430180·0 | 516068·0 | 0.46 |
| 3016 1002 | 0.19 | 430116·0 | 516087·5 | 2.44 |
| 3016 1101 | 1.22 | 430128·2 | 516146·0 | 0.30 |
| 3115 4901 | 0.20 | 431480.5 | 515920.5 | 2.70 |
| 3115 5802 | 0.15 | 431543·0 | 515893·0 | 2.44 |
| 3116 5701 | 0.31 | 431520·0 | 516769·5 | 0.30 |
| 3116 5709 | 0.15 | 431529·0 | 516762·5 | 0.30 |
| 3116 6003 | 1.80 | 431670·5 | 516035·5 | 1.70 |
| 3116 6501 | 0.20 | 431645·5 | 516503·0 | 1.30 |

Table 3.7 - Distribution of known Peat Deposits outside of the Town Centre Area




LEGEND

| | |
|---|---|
| Borehole location | |
| Borehole number | 2914 1105 |
| Section Line | |
| North Embankment | W(N) - E(N) |
| Cross Section | A - A |
| Cross Section | B - B |

Scale 1:7000

Figure 3.18 - Borehole Locations within the River Skerne Corridor

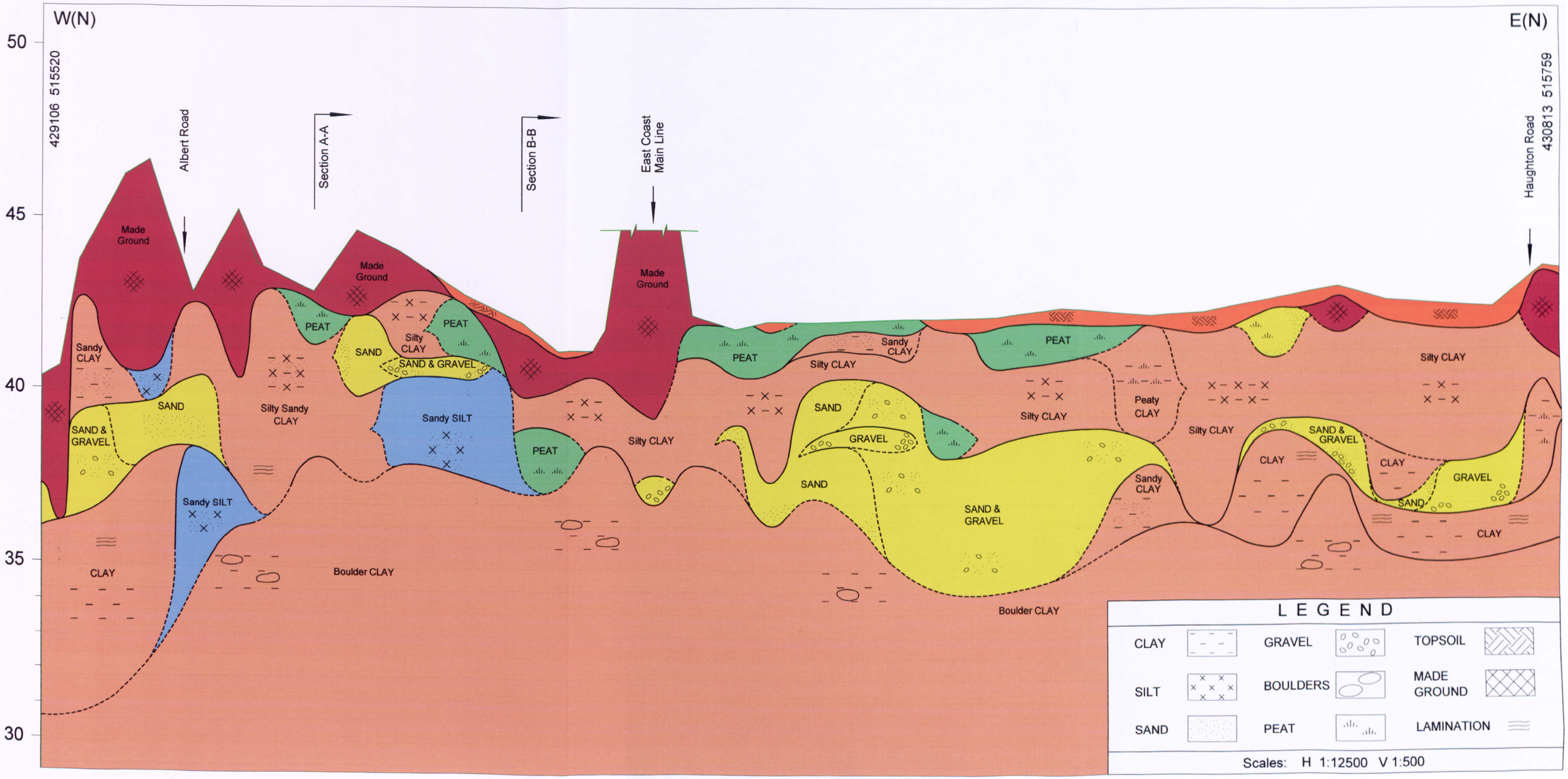



Figure 3.19 - Longitudinal Section, North Bank of River Skerne

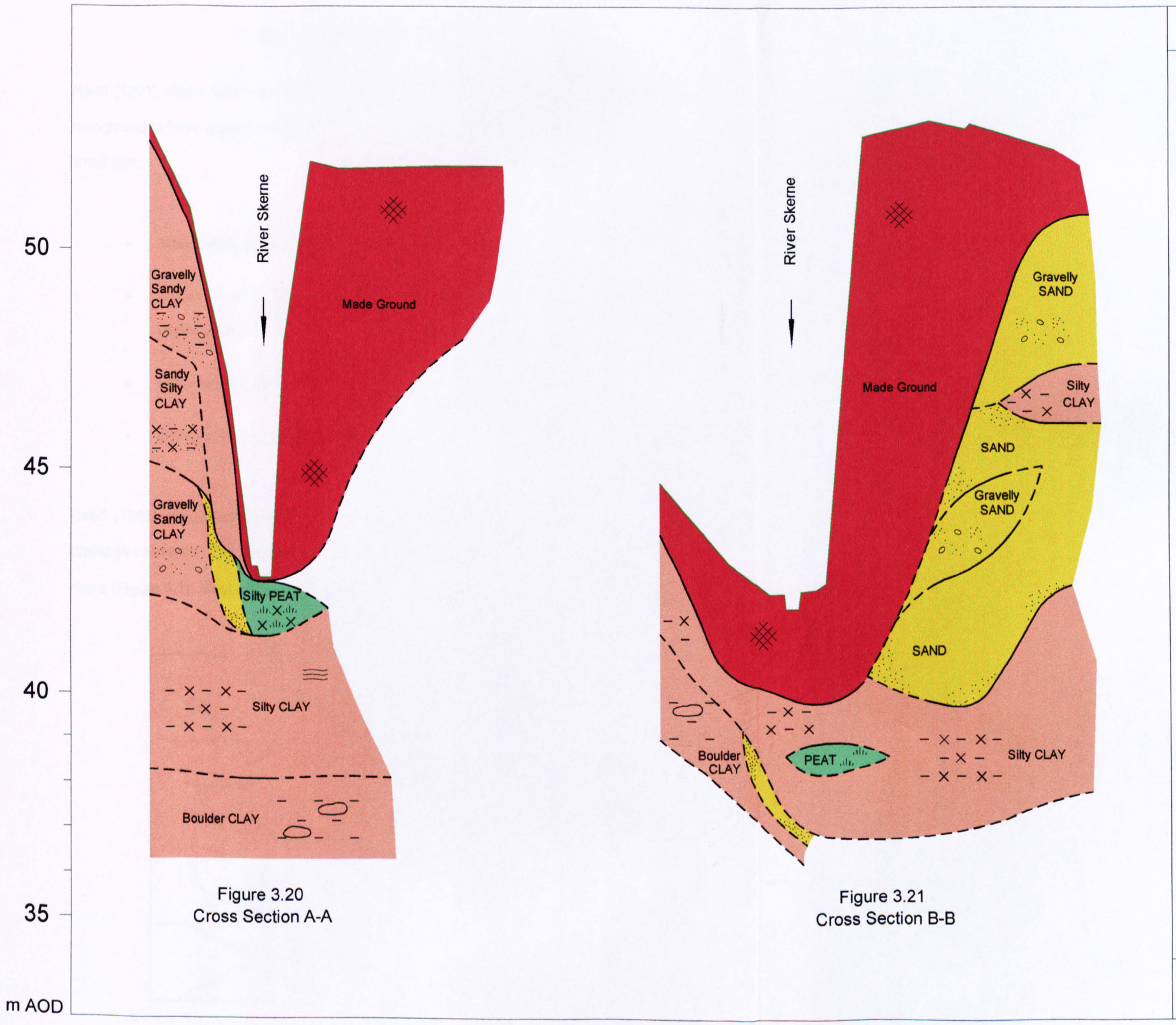



Figure 3.20
Cross Section A-A

Figure 3.21
Cross Section B-B

Figures - 3.20 & 3.21 Cross Sections A-A and B-B of the River Skerne Valley

# 4.0 GLACIAL DRAINAGE

Reed (1901) states that there are four classes of drainage modifications which can be recognised to have occurred in the East Yorkshire region, of which the study area forms a small part;

- adjustments due to the characteristics of the rocks and geological structure.
- adjustments marking the progress of a river through a normal cycle of development.
- adjustments caused by movement of elevation or depression.
- changes induced by glaciation, especially by the deposition of glacial drift.

Reed (1901) suggested that all four factors were at play in the forming of the glacial drainage channels. He produced a primary drainage system of the original consequent rivers (Figure 4.1), all of which had a general direction of flow to the east or south-east.

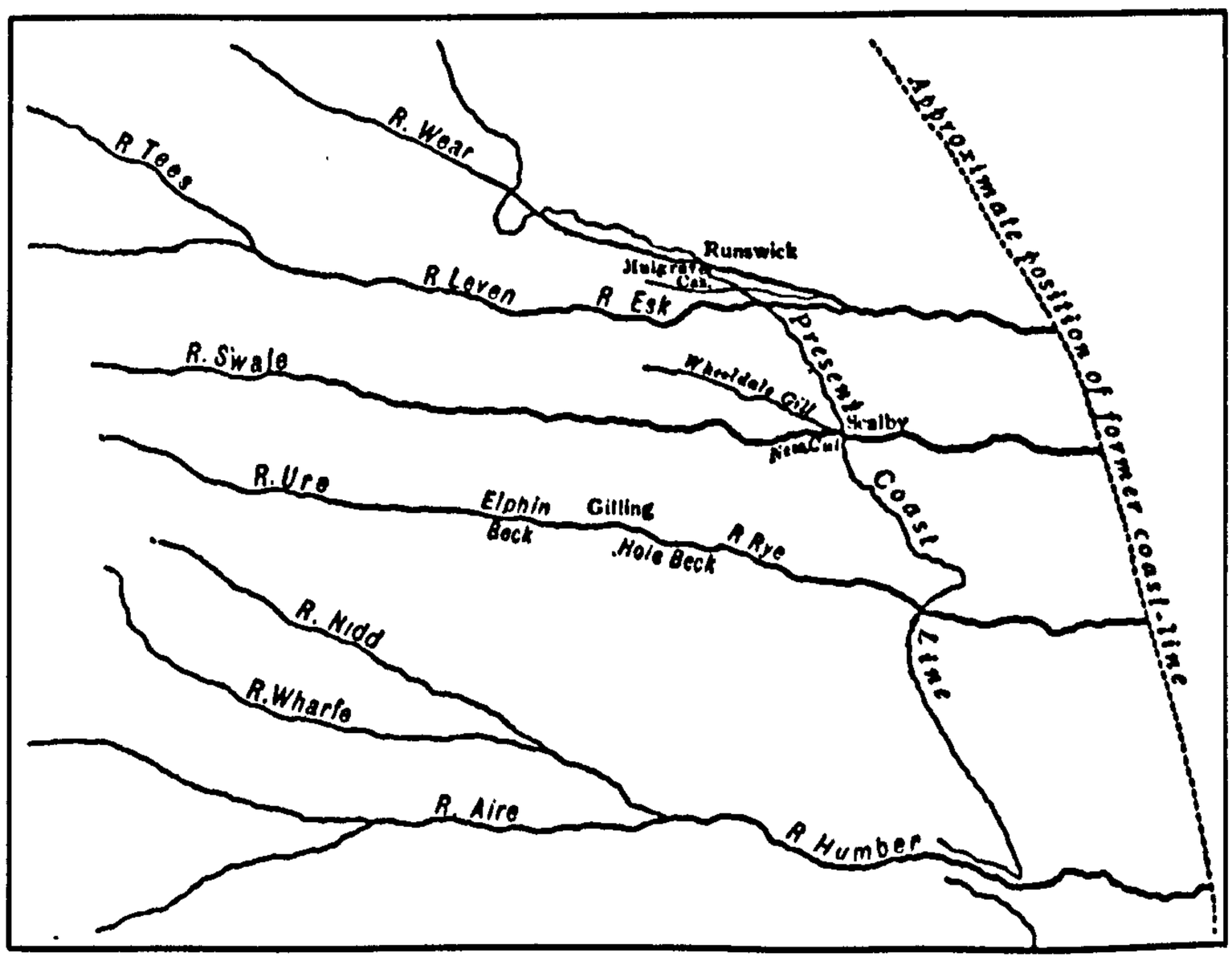



Figure 4.1 - Diagrammatic Map, showing course of Original Consequent Rivers (Reed, 1901)

This study is concerned with the section of the River Tees and the major tributaries covered by the north-western portion of Reed's map.

Fawcett (1916) and Trotter (1929) indicated that the Barnard Castle district once formed part of an uplifted Tertiary peneplain with a gentle easterly tilt and that the consequent drainage patterns were partly governed by the tilt of the peneplain and partly by the general east-west 'grain' of the country overlain by Carboniferous rocks. Mills (1976) concluded that a series of eastward flowing consequents resulted, as illustrated by Figure 4.2. However, Dunham (1990) considered the district to be part of The Teesdale Dome, a structure of considerable dimensions, and may well have originated during the Hercynian as the counterpart of the basin, providing a barrier, between the western and eastern areas of Permian sedimentation, which was perhaps reduced by erosion before Triassic times. Furthermore Dunham contends that because of the freshness of the fault-scarps of the Pennine and North Stublick faults, and of the feature made by the upturning of the beds towards the Lunedale Faults, there is little doubt that the last elevation along these lines was not older than the Tertiary.

The broadly parallel system of consequents developed in early Tertiary times, appear to have been modified before the onset of glaciation (Mills 1976). The main modification was by the development of active subsequent streams, given in Figure 4.2, which has been reproduced from Mills.

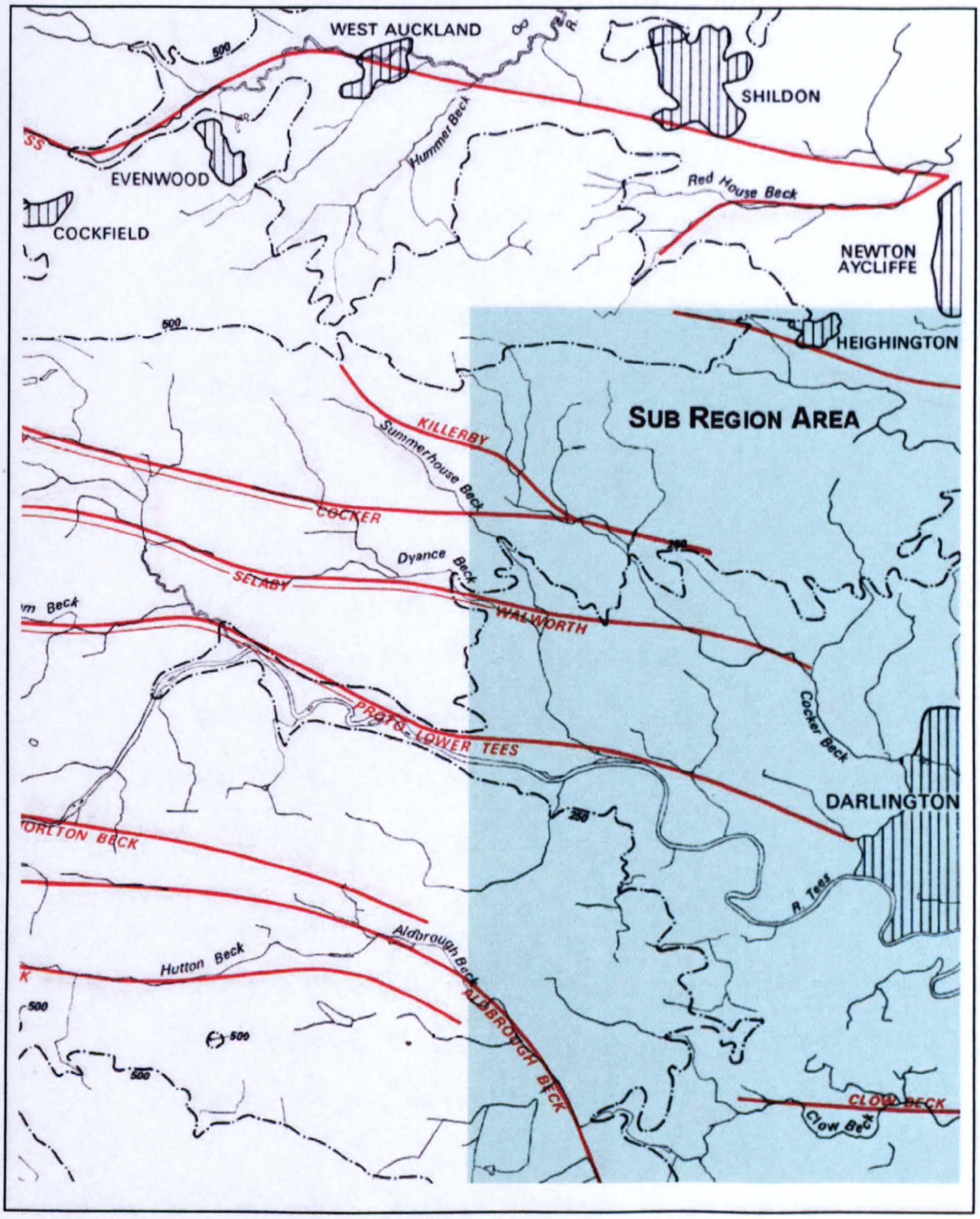



Figure 4.2 - Elements of the Early Tertiary Drainage System in the Barnard Castle District (modified from Mills, 1976)

The subsequent streams are commonly located on faults, in this case on the line of the Staindrop fault and associated faults. Mills further stated that perhaps the greatest single event in the development of the drainage system of this area took place at the late-glacial or early post glacial stage when the Upper Tees and Greta drainage systems were captured by a tributary of the proto-Tees Figure 4.3.

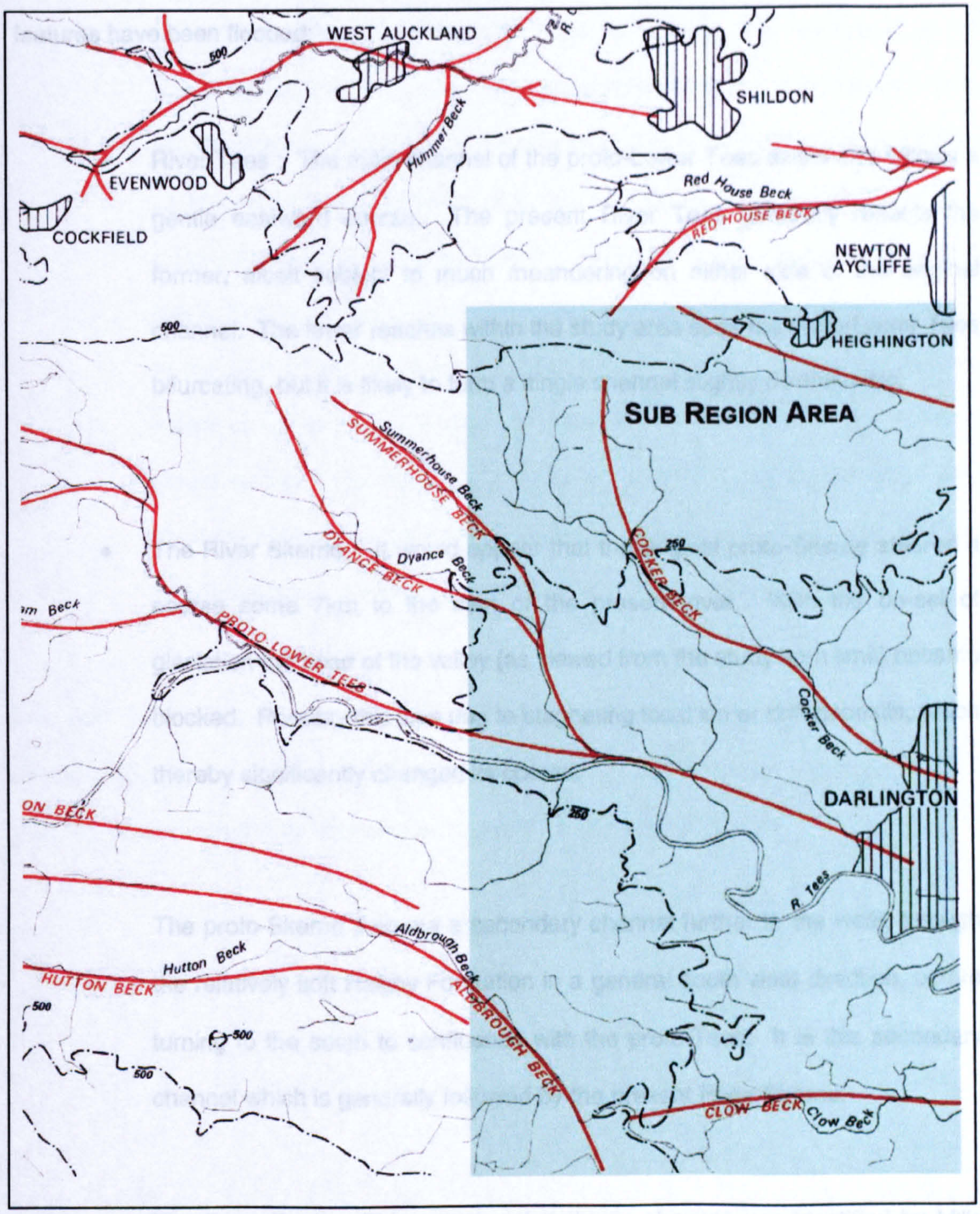



Figure 4.3 - Elements of the Pre-glacial Drainage System in the Barnard Castle District (modified from Mills, 1976)

As a result of this current study, the topography of rockhead is redefined and details of the drainage features together with present rivers and a main tributary are superimposed onto the rockhead map (Figure 4.4).

To add dimension to the results, Figure 4.5 has been produced to show a 3-D image of the study area at rockhead. To add a degree of realism to the model, the drainage

features have been flooded:

- River Tees : The main channel of the proto-Lower Tees exists and follows a gentle eastward course. The present River Tees generally reflects the former, albeit subject to much meandering on either side of the original channel. The lower reaches within the study area sees the proto-Lower Tees bifurcating, but it is likely to form a single channel slightly downstream.

- The River Skerne : It would appear that the original proto-Skerne steered a course some 7km to the east of the present river. With the on-set of glaciation the head of the valley (as viewed from the study area limit) became blocked. Possibly this was due to stagnating local ice or drift deposits, which thereby significantly changed its course.

  The proto-Skerne then cut a secondary channel further to the west, through the relatively soft Raisby Formation in a general south west direction, before turning to the south to confluence with the proto-Tees. It is this secondary channel which is generally followed by the present River Skerne.

- The Dene Beck : This pre-glacial drainage channel was identified by Mills (1976) Figures 4.2 and 4.3. In Figure 4.5 a well defined channel charts a course due east west. A comparison with the present Dene Beck course suggests an extremely good match between the two.

- The Lake : On the blocking of the proto-Skerne's primary channel somewhere to the north of this study area, a lake was formed on the

downsteam side. The shape and depth of the lake was influenced by the rate of dissolution of the underlying evaporites and time - a process which is still proceeding. At its zenith, the lake extended to a maximum width of 8km as measured in an east-west direction and about 14km along the original proto-Skerne Valley. The lake discharged in the south (approximately at NZ 438 510) to the proto-Tees via bifurcated channels. These channels merged to the east of the study area. Subsequently, the lake basin and the pre-glacial channels became infilled by thick drift deposits (up to 50m) forming buried valleys. The borehole information within the lake region gives very good descriptions of the solid geology but only generalised accounts of the drift sequence, therefore not specifically confirming these findings.

The work from this study substantiates the early theoretical thesis of Reed (1901) and confirms the concepts expounded by Mills (1976) in respect to pre- and post-glacial drainage systems, but only within the confines of the present study area.

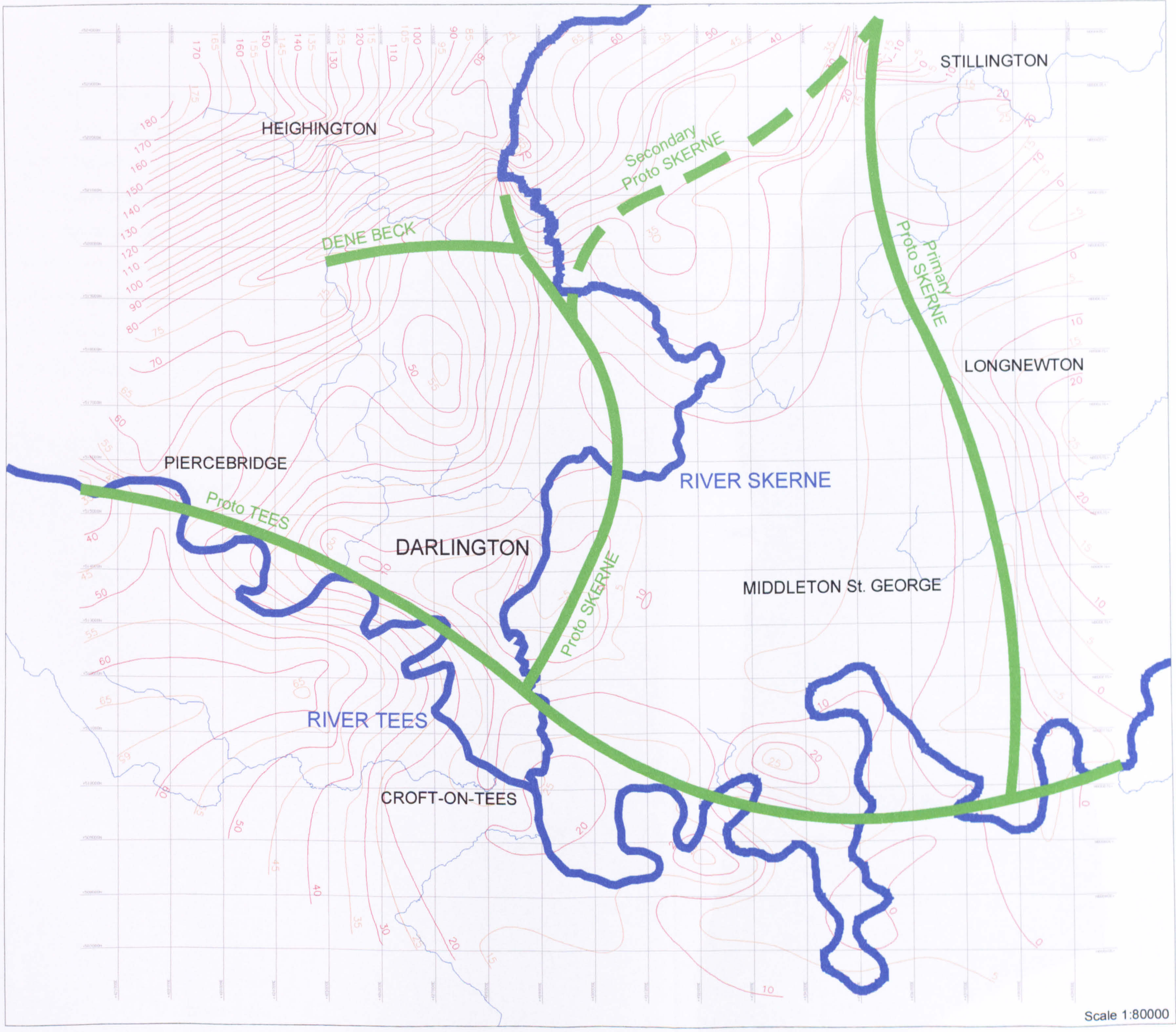



Figure 4.4 - Early and Modern Drainage Systems in the Darlington Area

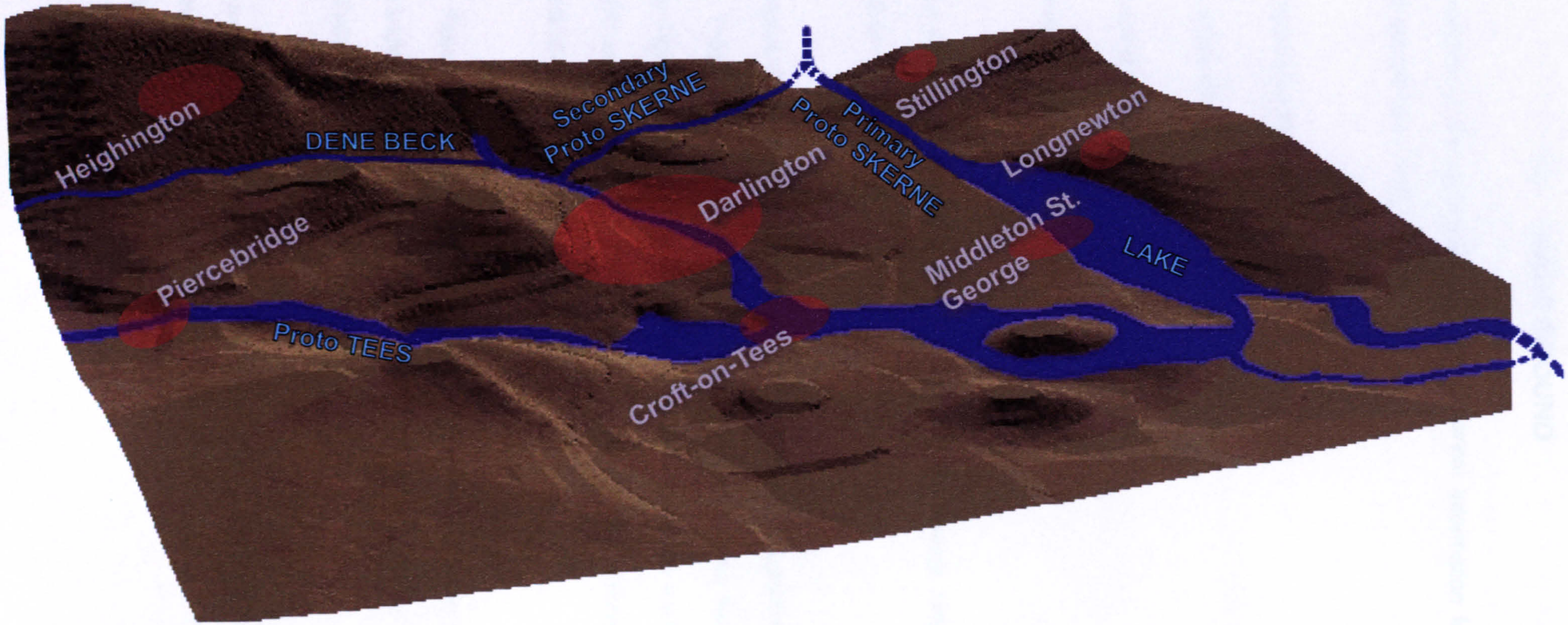



Figure 4.5 - 3D Image Of Glacial Drainage Channels

# 5.0 MADE GROUND

During the compilation of the geological data and historical information four principal sources of made ground have been identified:

- Accumulated deposits.
- Localised filling.
- Household waste.
- Industrial waste.

The location and extent of the made ground are shown in the various longitudinal and cross sections given in Chapter 3.0.

The ground contours of the 1852 town centre are given in Figure 5.1 (ignoring the deeper river channel). These values are between 1.5m to 2.0m greater than the subsequent models shown in Figures 5.2 - 5.4. This difference is consistent with the work undertaken by Harrison c1876 when he lowered the river bed level in an attempt to solve the serious flooding problems occurring in 1875.

From the River Tees to Victoria Road Bridge, individual boreholes indicate waste tipping accumulations ranging in thickness from about 1.30m to greater than 2.70m in the South Park area. Typically the made ground comprises a matrix of:

*'Medium dense orangey brown clayey very sandy silt with occasional gravel and cobbles including glass jars, porcelain, bone and brick fragments.'* (BH No 2812·4905, 0.70m - 1.20m).

In one borehole No 2812·4905 (NZ 428437 512917) petrochemical odours were recorded. Even greater depths of made ground were recorded at the Darlington football ground at Feethams. Borehole No 2813·9901, (NZ 428912 513920) indicates 3.30m of waste material build-up.

From Victoria Road Bridge to St Cuthbert's Way, a distance of about 1km the borehole evidence shows that the area had been subject to considerable remodelling over many years with made ground thicknesses from about 1.50m to 4.88m with an average of about 2.80m along the river embankments. Figure 3.16 shows the river terrace to be about 0.41km wide and its sediments comprise a thick layer (approximately 3m to 4.5m) above the alluvium.

The whole of the built up area of the 1850 settlement is overlain by made ground (Figure 3.17). This is thickest at the western embankment and feathers out to about 0.50m at a line parallel to the river (following the contours) at about Skinnergate. This fill is a combination of accumulations and localised infilling with inert material. A similar pattern is repeated, averaging about 1.20m over the flood plain (Hargreave Terrace area), up to the main railway line. The purpose of these infilling operations was to reclaim wetlands within the floodplain for cheap industrial and residential development. Examples include the construction of Pease's Mill and the associated millpond and mill stream and also the housing development of the Low Parks Estates (Hargreave Terrace/Backhouse Street area).

Much of the fill material found in the wider river valley downstream of the Victoria Road Bridge is likely to be the arisings from Harrison's excavations of c1876.

During the mid-1800s, manufacturing industries were active within the boundaries of the settlement, primarily:

- Iron foundaries.
- Tanneries.
- Wood dying.

No specific trace of these industrial activities has been detected from the borehole logs; however, the principal areas of manufacture are known and shown on Figure 5.1.

St Cuthbert's Way to the Haughton Road Bridge: the general pattern of made ground is similar to lower reaches of the river. The made ground varies in thickness from 0.5m to 8m. Much is contaminated by gas works waste and the coal distillation plant which occupied the site since the early 1800s, originally manufacturing town gas from coal with the associated by-products. Several boreholes, of varying age, are very specific about the nature of the contamination and relevant extracts are given in Table 5.1.

| BH No | Borehole Log Description | Depth (m) |
|---|---|---|
| 2915·3103 | ... occasional coal tar material (strong chemical smell). | 1.40 |
| 2915·1302 | ... water polluted with tar. | 4.11 |
| 2915·1502 | ... with traces of tar and liquor. | 4.27 |
| 2915·1520 | ... heavily contaminated with black coal tar. | 1.00 |
| | ... clay impregnated with tar residues. | 2.00 |
| | ... soft, stained green/black (with tar and creosote) ... | 3.00 |
| 2915·1521 | ... Smell of manufactured gas and tar. | 2.00 |
| | ... Possibly contaminated with coal tar seepage | 3.00 |
| 2915·0502 | ... with asbestos. Tarry odour. | 0.50 |
| | ... Strong tarry odour. | 0.90 |
| 2915·1516 | ... Slight tarry odour. | 0.50 |
| 2915·1517 | ... Strong smell of creosote. | 1.80 |

Table 5.1 - Schedule of known areas of ground contamination arising from former Gas Works

The greatest depth of artificial deposits is located between Albert Road Bridge and the main railway line. These deposits, from the former Iron Works at Albert Hill, are of slag and extend in places throughout the width of the natural flood plain. The results of this industrial waste tipping are shown at Figure 3.19 and Figure 3.20, both of which give typical cross sections of the river and its immediate environs.

In October 1884, Thomas Smith, the Borough Surveyor reported to the Streets Committee (see Chapter 2.0 Flood [1886]) that the Darlington Iron Company had tipped slag to such an extent *'that the river bed was almost filled in with slag'*. Figure 3.21 illustrates that not only had the bed been covered with slag but a wider area on the opposite bank (northern) had also been used for tipping purposes. Figure 3.22 also shows that the northern bank had been exploited as a waste tip, much of which still remains in-situ.

From the Main Railway Line Bridge to Great Burdon Bridge the extent of the made ground diminishes and is restricted to localised areas. Nevertheless, some areas are filled up to 3.00m deep as shown by BH No 3015·4701 (NZ 430463 515719) and comprise rubble and clay.

Limited chemical analyses are available for this area which were carried out in June 1968 for the construction of a main outfall sewer. These indicate that both the soil and ground water were almost neutral in nature and generally contain negligible amounts of sulphates. The one exception was a water sample obtained from Borehole No 2915·1503 (NZ 429117 515544) which contained a relatively high concentration of sulphates. Testing carried out in February 1996 in the area of the gas works noted contaminants within soil and ground water samples to contain cyanide, petroleum, hydrocarbons, lead and mercury. The pH values were similar to the 1968 results, in that the values were near neutral (ranging from 7.3 to 8.2; river samples ranged from 7.4 to 8.7).

Other than the manufacture of gas and coal tar at the gas works adjacent to John Street and the River Skerne, no other major industrial processes are recorded which could have leached into the river via ground water movement.

Borehole No 2915·3103 (NZ 429331 515114) is approximately 0.5km downstream of the gas works and demonstrates the permeability of the granular strata and its capacity to transport contaminants considerable distances. It is possible that the petrochemical odours recorded in Borehole No 2812·4905 (NZ 428437 5129817) in South Park are related to the gas works source, although it is known that leakage occurred from a petrol station off Victoria Road circa 1970.

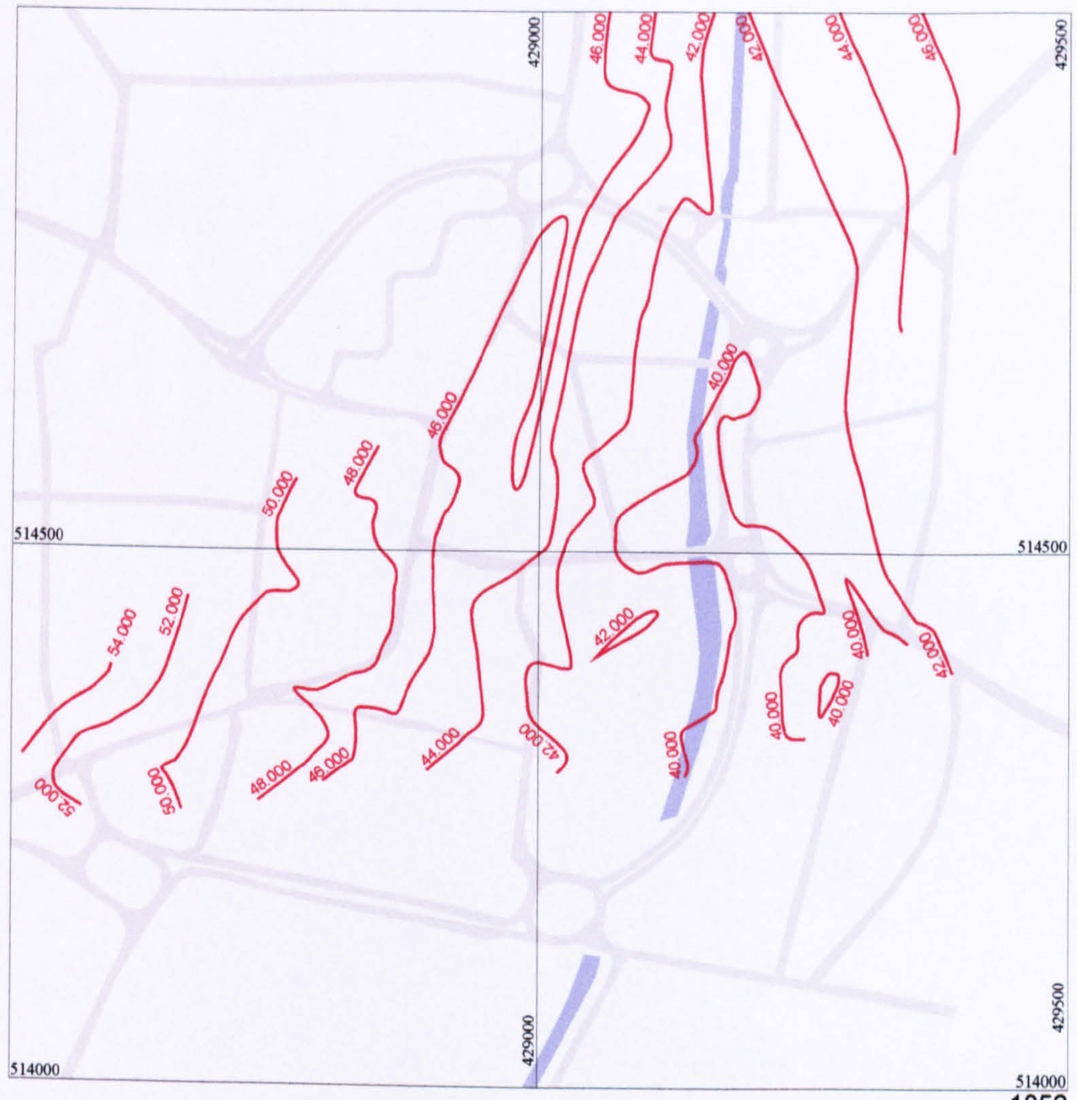



Figure 5.1 - Contours 1852

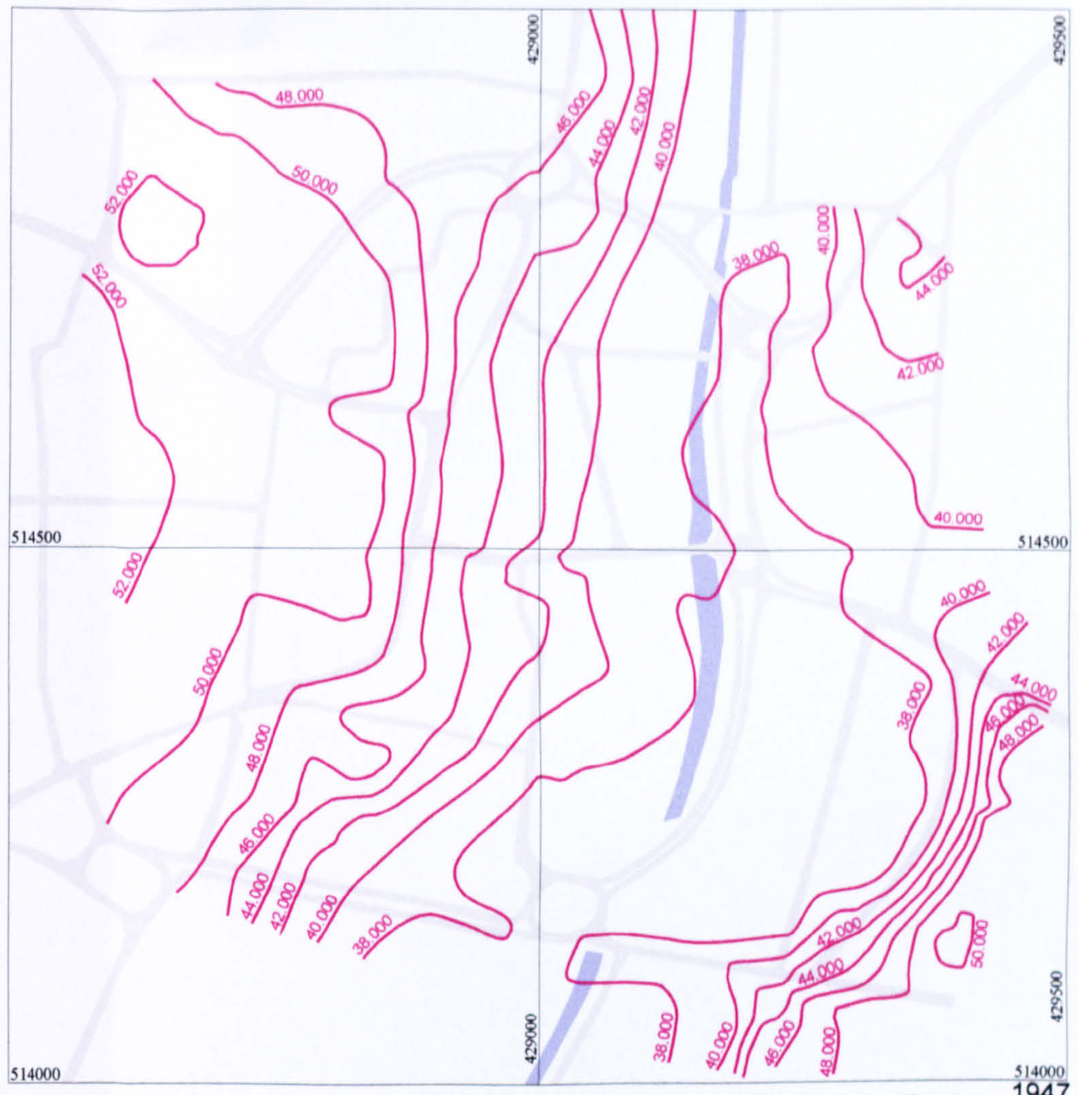



Figure 5.2 - Contours 1947

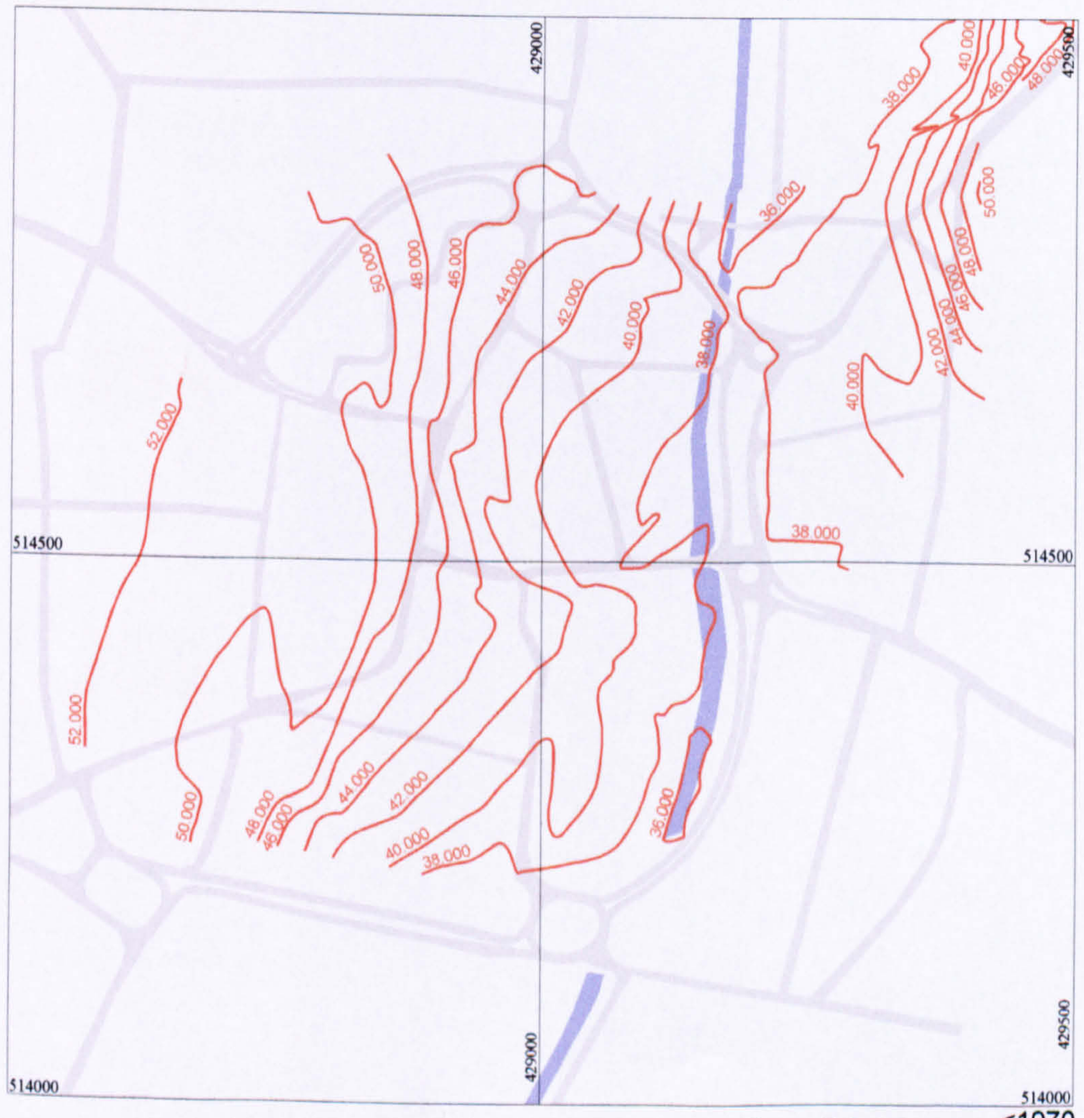



Figure 5.3 - Contours <1970

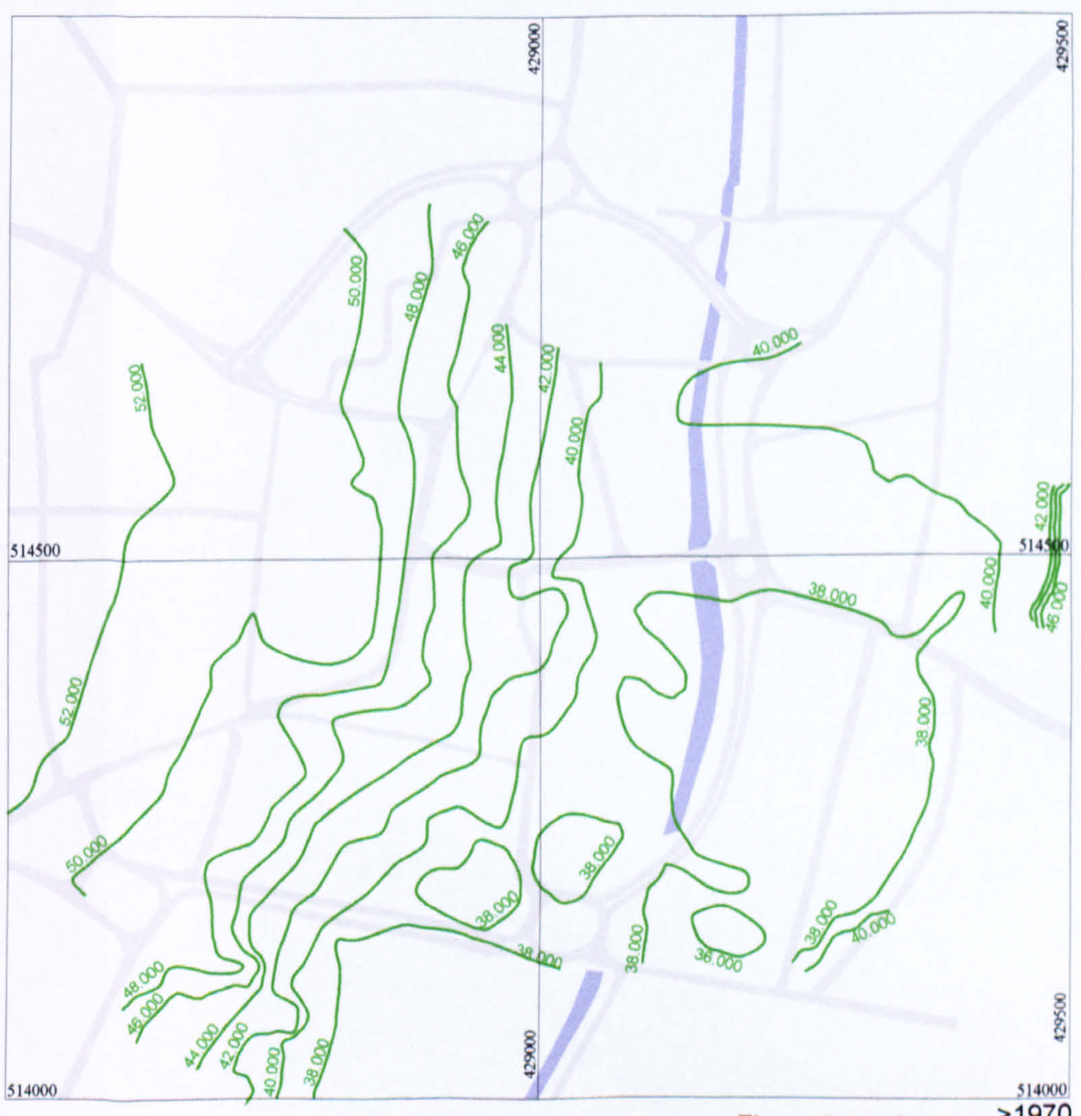



Figure 5.4 - Contours >1970

Figures 5.1 to 5.4 - Ground Level Contours Through Time

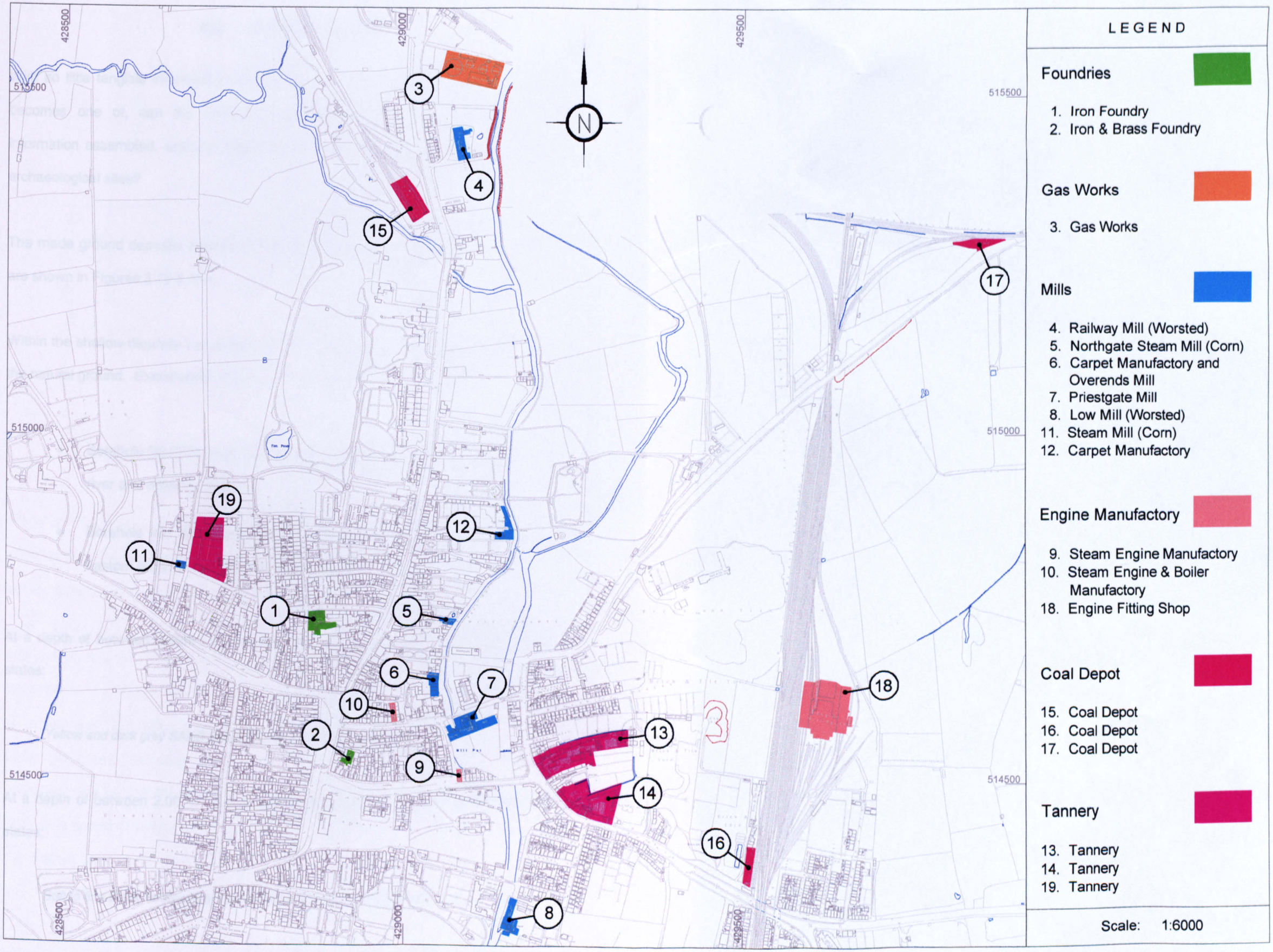



Figure 5.5 - Areas of Former Industrial Activity within Darlington Town Centre

# 6.0 ARCHAEOLOGY

With so little tangible information available for the archaeology of Darlington, the issue becomes one of, can the combined geological, topographical and cartographical information assembled, assist in predicting the likely locations and horizons of potential archaeological sites?

The made ground deposits combined with the drift deposits within the town centre area are shown in Figures 3.16 & 3.17.

Within the shallow deposits two anomalies are apparent within the river terrace zone and the natural ground. Examination of two boreholes highlight these, namely:

- Borehole No 2914·0205 (NZ 429085 514232) located on the west bank of the river and drilled in 1958.
- Borehole No 2914·1204 (NZ 429199 514240) located opposite on the eastern bank of the river and drilled in 1980.

At a depth of between 1.52m - 2.51m below ground level at BH No 2914·0205 the log states:

*Yellow and dark grey SAND with traces of peat and decayed timber.*

At a depth of between 2.00 m - 3.20m below ground level at BH No 2914·1204 the log states:

*Soft to firm black sandy clayey PEAT with scattered decayed wood fibre.*

Figure 6.1 diagrammatically illustrates the relationship between the two boreholes.

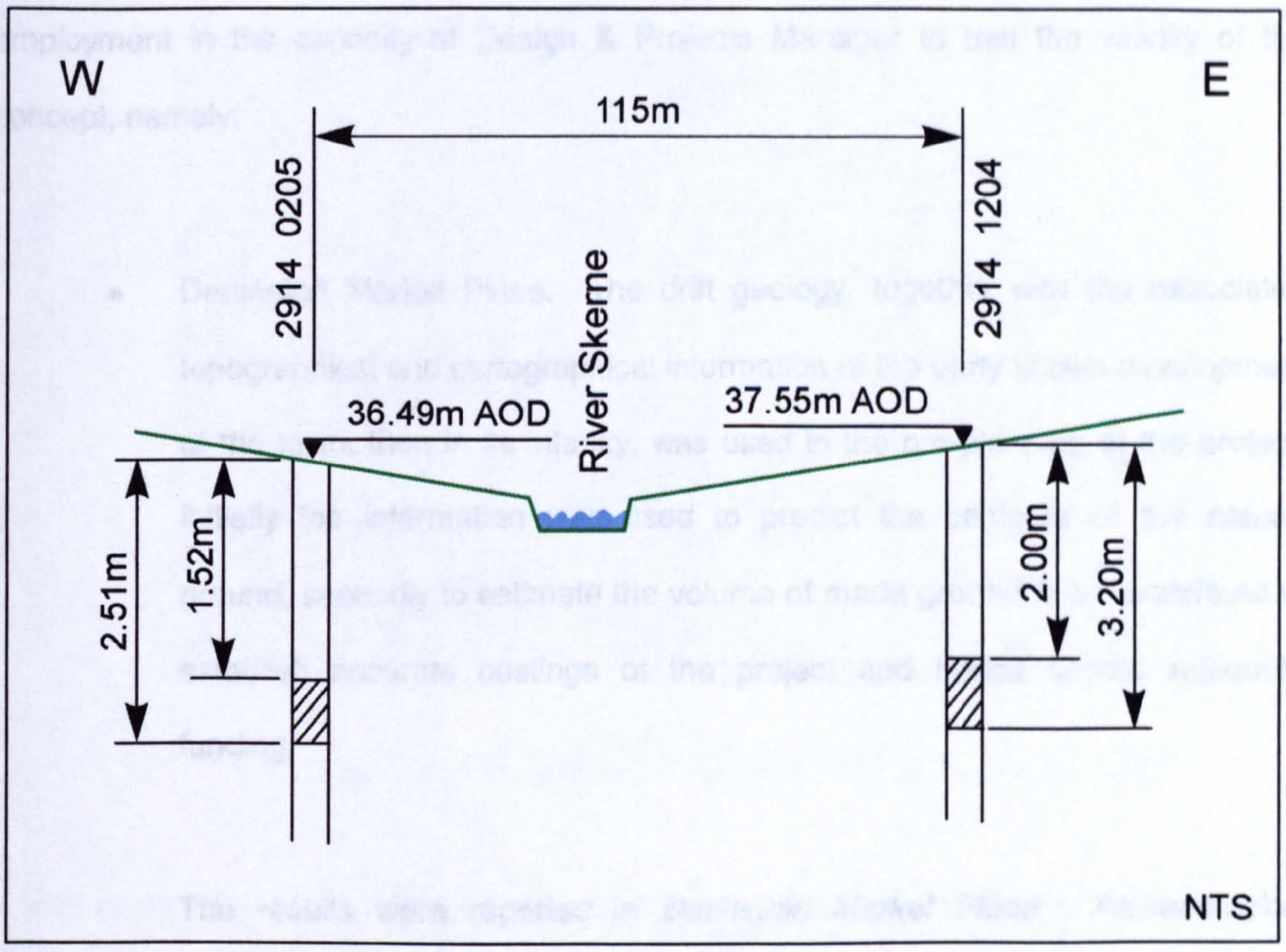



Figure 6.1 - Relationship between Borehole Numbers 2914·0205 & 2914·1204

These boreholes were drilled twenty two years apart. It is most unlikely that the same driller/geologist was involved in the interpretation of the logs, therefore, the findings are almost certainly independent of one another.

It is unlikely that the description of *decayed timber* and *decayed wood fibres* may relate to the remains of a former natural woodland, since no other instances have been recorded in similar peat deposits. It is possible that the *wood fibres* referred to in BH No 2914·1204 could have been pieces of timber shattered by the action of the drilling operation. The probability is that the timber was associated with a man-made structure such as a bridge or jetty construction. No other similar references have been found in the dataset comprising 1029 boreholes. When redevelopment proceeds at these sites any peat and wood should be retrieved and tested in order to clarify the position.

Throughout the duration of this study, two opportunities arose in the course of my

employment in the capacity of Design & Projects Manager to test the validity of the concept, namely:

- Darlington Market Place. The drift geology, together with the associated topographical and cartographical information of the early known development of the town, then in its infancy, was used in the pre-planning of the project. Initially the information was used to predict the contours of the natural ground, secondly to estimate the volume of made ground to be excavated to establish accurate costings of the project and hence secure adequate funding.

  The results were reported in *Darlington Market Place : Archaeological Excavations* (Carne & Adams, 1994) confirming the predictions.

- The River (Skerne) Restoration Project. The drift deposits for the river valley (Figures 3.19 & 3.20) were used to identify saturated peat deposits within the river terrace zone. Two trial holes were excavated and the results were reported by Northern Archaeological Services under NAA 95/12.

  The peat deposits were found as predicted by the extrapolated borehole data and furthermore, an Elk jaw bone dated as 10,000 years BP was discovered. Figure 6.2 shows The Darlington Elk jawbone (top) and a modern specimen (below).

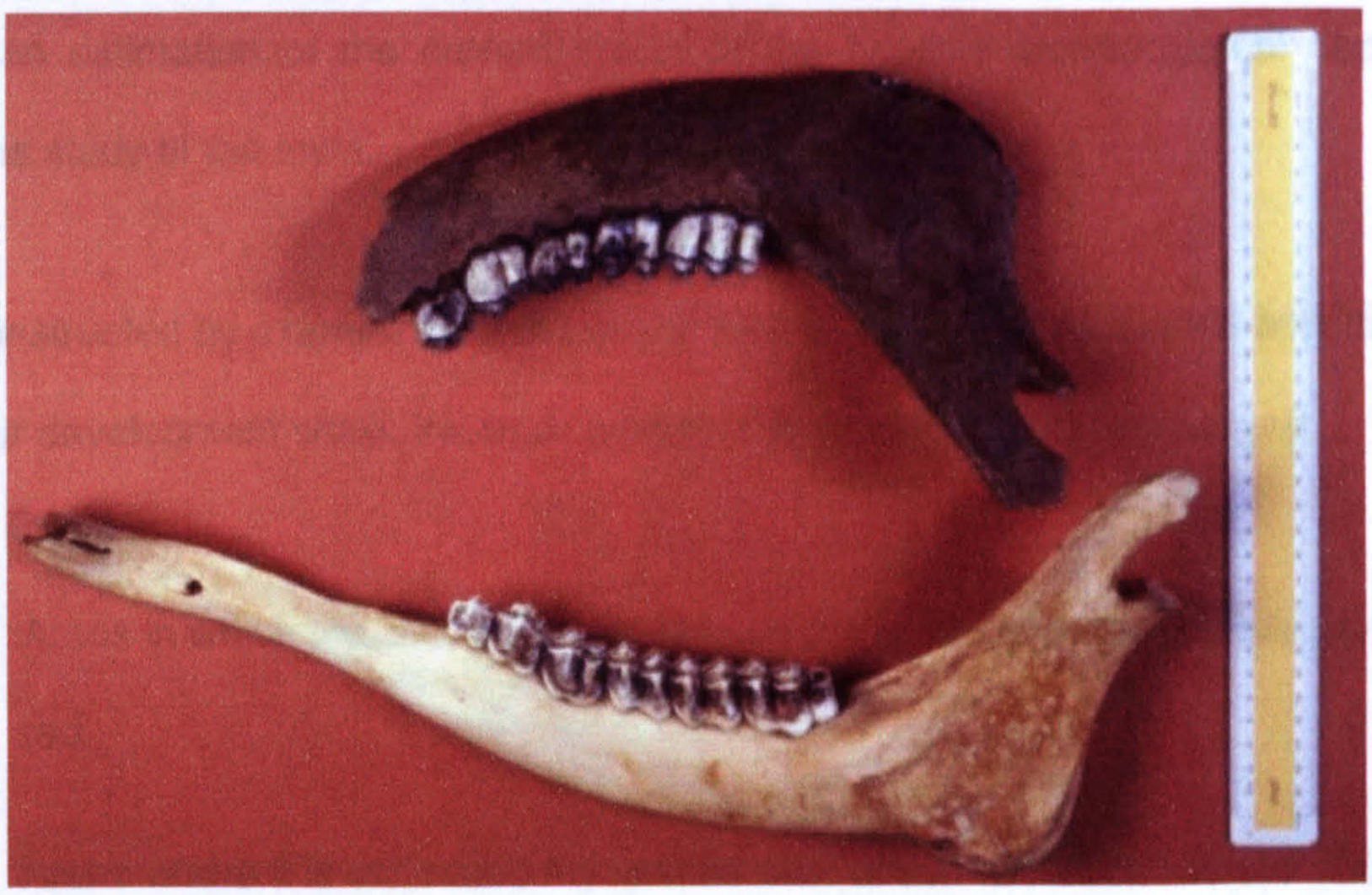


Figure 6.2 - Elk Jawbone discovered in the Skerne Valley, 1995

A third opportunity arose in 2001 when my employer, Darlington Borough Council, sought the author's advice on a proposed development at Commercial Street (NZ 428932 514830). In this case, the combined information suggested that the archaeology on the site had been totally destroyed. This proved to be the case. The results were reported by the University of Durham (ASUD 844).

There might be a relationship between topographical features and archaeology - the boreholes pick up river terraces and the terrace identified in the market place excavation might have formed the medieval town. Stakeholes were identified along the terrace which, it was thought, might reflect early prehistoric activity, but the carbon date from one was calibrated AD 1010-1152 (65%) or 980-1170 (95%) (Carne & Adams 1997). This might indicate that the stakeholes and the terraces were used as a boundary in this period.

As development has taken place, much of the shallow archaeology has either been greatly disturbed or destroyed. The deposits within the old town limits have suffered the most through modern redevelopment. Such developments have probably destroyed previous important areas by the excavation of deep foundations and basements. Figure

6.3 shows an estimation of the current status of the shallow archaeological deposits, based on this study of the town.

This was constructed by examining all of the planning and building regulation applications deposited for development within the town centre. Four separate areas emerged:

- Areas in which the shallow deposits have been totally destroyed are shown in red.
- Areas where it is estimated that partial destruction has occurred are shown in green. The last have been due to several factors including remodelling of the ground profile, building works and the provision of service pipes.
- Areas immediately adjacent to the town centre where insufficient information is available to make a judgement are shown grey.
- Areas where little or no disturbance appears to have been undertaken are shown white.

The four white areas include two adjacent to the River and lying on the western banks with the other two lying within the medieval core of the town.

St Cuthbert's Churchyard is known to have been landscaped in the early 1970s. This work involved excavations for paths, seating areas and large raised planting boxes; however, in terms of the shallow deposits, the works were superficial. The Bus Station was constructed on open land (Feethams Field) in 1959. The construction comprised piled foundations, ground beams and concrete floor slab. Consequently, a large portion of the underlying ground is considered to be undisturbed. The area now occupied by Abbotts Yard car park lies within the medieval sector of the town and nearby to the open land in Bondgate which may have been a previous market area. Only superficial disturbance of this area has been identified. Finally, the Blackwellgate area at the very centre at what appears to have been the original burgage plots, seems to be undisturbed

other than for surface trenches and some buildings at the eastern end.

Figure 6.3 - Estimation of Undisturbed Shallow Deposits within Darlington Town Centre

# 7.0 HYDROLOGY

As with every other settlement, prior to the establishment of piped water, the early Darlington settlement (pre-1870) was dependent upon natural sources for the supply of drinking water. After that date a piped mains water distribution system was introduced. The drinking water could have come from one or all of three sources, namely:

- Artesian water from the underlying Magnesium Limestone aquifer.
- Perched water tables within the glacial sand and gravel layers.
- The River Skerne.

When Borehole No 2814·9205 (NZ 428963 514224) was sunk in 1911 by Messrs C Isler and Company for the Pure Ice Company, artesian water was reported (Cooper *pers com*). Similarly, from Borehole No 2821·0301 drilled for the BGS at Monk End (NZ 42800 51008), artesian water was recorded which rose to a height of 16-20 ft (4.8-6.0m) above ground level and produced about 30,000 gallons per hour (135,000 litres per hour) (Cooper, 1994). Granville (1841) in his account of the Spa at Croft records:

> *At a very short distance from a very humble-looking cottage is the spring or head of the well* (near the Spa Hotel).
>
> *The water keeps incessantly running, coming in from the head well at the rate of about twenty-four pints to the minute. It is beautifully clear and transparent, and smells of its peculiar gas.*

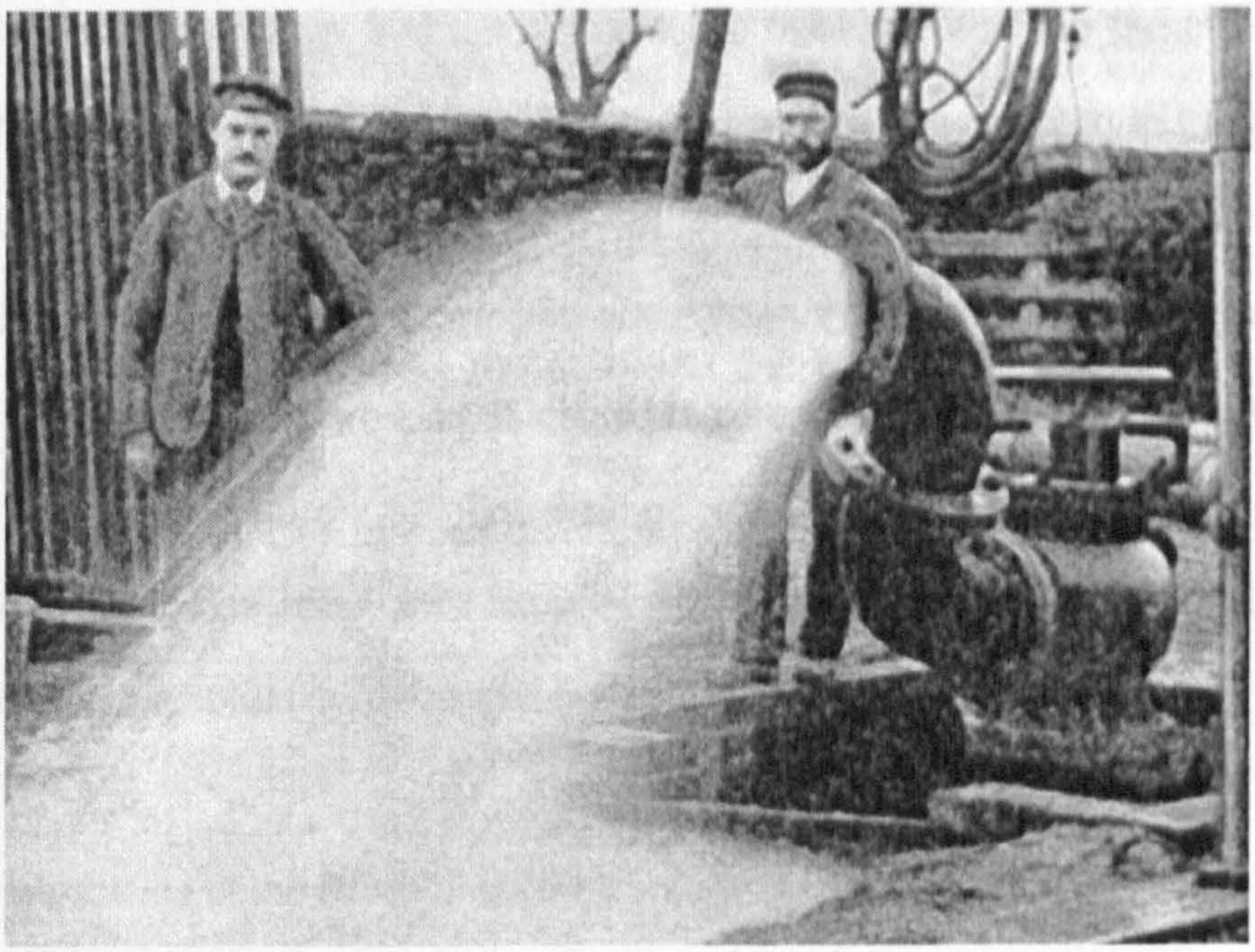


Figure 7.1 - The Overflow of an Artesian Well at Bourn, Lincolnshire drilled by Messrs Isler and Company, c1890 (After Thresh)

The hydrostatic head was considerable and to illustrate the intensity of similar conditions of artesian water Figure 7.1 is given.

Figure 7.2 shows contours of hydrostatic head for the region, illustrating the energy available to drive the water through the main aquifers (and potential to dissolve evaporites).

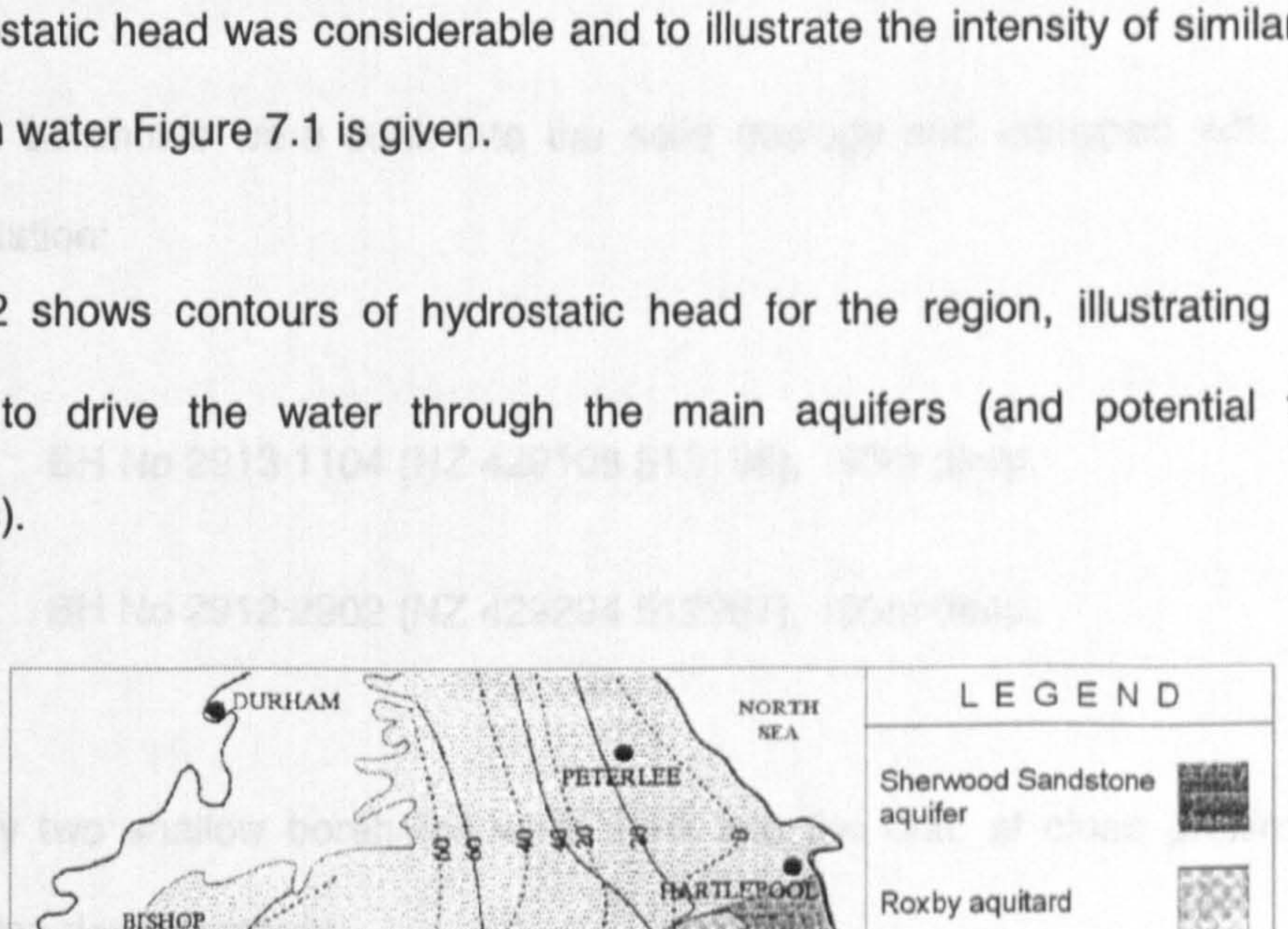



Figure 7.2 - Hydrostatic Head Contours in the Darlington Area (Younger 1994)

It is known from the geology that the aquifers are fractured and the ground is founded arising from the dissolution of the evaporites. Settlement has resulted in the fissuring of the overburden clays. The combined effect of ground movements have opened up communication passages for the artesian water from the aquifer to the surface or near surfaces. These conditions are almost identical to the model proposed by Thompson *et al* (1996) for Ripon (see Figure 7.3). The distinguishing variation is that of the thickness of overlying drift; Ripon has about 10m cover whereas Darlington has about 30-40m. Figure 7.3 illustrates a conceptual model of ground water flows in the Darlington area.

One of the objectives of the ROSES Study (Lamont-Black *et al.* 2002), of which the author is a research team member, was to attempt to establish if water from the Permian aquifer entered and permeated through the Darlington drift deposits. This exercise was carried out over a three year monitoring and testing programme (1997-2000).

Two deep boreholes were sunk into the solid geology and equipped with appropriate instrumentation:

- BH No 2913·1104 (NZ 429108 513198), 93m deep.
- BH No 2912·2902 (NZ 429294 512967), 105m deep.

Additionally two shallow boreholes were sunk into the drift, at close proximity from its neighbouring deep borehole:

- BH No 2913·1104 (NZ 429109 513203), 21m deep.
- BH No 2912·3901 (NZ 429300 512963) 27.5m deep.

The results showed that permanent hydraulic connections exist between solid and drift.

It is obvious that perched water tables are charged from both the Permian aquifer and the watershed. With the degree of filtration afforded by the various arenacous layers within the drift (Figure 3.16) the resultant supply, in natural state would be both good quality and plentiful.

However, it is worthy of note that Ranger (1850) stated:

> *It is no uncommon thing to see the liquid from stables, cow-byers, slaughter-houses, piggeries, dunghills, and privies, running through the passages from the courts across the footways into the open channel in the streets, and so along to the nearest gully-hole.*

This effluent also percolated into the sand bodies from which the wells and pumps drew their water supply (Figure 3.16). The majority of inhabitants were totally dependent upon this supply as confirmed by the statement made by Mr Mason, a Civil Engineer, in his evidence to Ranger:

> *The occupiers of 924 tenements derive their supply from 393 pumps, in 8 cases from draw-wells, and in 1,470 from 19 public pumps. At Bank Top, a portion of the occupiers of 110 tenements procure their supply from two public pumps, and the others are obliged to beg or purchase a supply, travelling a distance of about an eighth of a mile, ...*

Mr Piper, medical officer, in his evidence to Ranger relating to Park street, stated that:

> *The supply of water is derived from a solitary pump, where chamber utensils and all kinds of vessels are washed: and I very much suspect the foul water thrown down the grate, passes down into the well, and is subsequently drunk by the unfortunate inhabitants of this crowded locality.*

Mr Fothergill, surgeon, in his evidence to Ranger, observed:

> *I consider the water of the town generally perfectly wholesome, and it is the best drinking water I ever met with anywhere; I know of no endemic disease that we have derived from the water.*

It is not clear if Fothergill is referring to the water supply in its natural uncontaminated state, if he was then it would be totally consistent with the findings of the hydrogeology.

Mr Piper continued his evidence by stating:

> *Those diseases have taken precisely the same track as the typhus in 1846 visiting the most filthy crowded localities and shunning the more open and cleanly parts of the town. The following has been their course:-*
>
> *All the yards in Skinner-gate, and the upper part of Bond-gate, Union-street, the principal portion of Catherick's-yard, in North-gate, and on the right-hand side of Priest-gate, all the yards down to the Skerne; Mill-entry, and the yards as far as the Pack Horse Inn; then past the Church-yard, to Clay-row, on the east side of the Skerne, yards in Clay-row, and Brunswick-street, from thence to Church-street, Park street, Chapel-street, Bridge-street, and Skerne-row. From thence to Bank-top, Green-street, Chancery-street, Silver-street, Adelaide-street, and Station-street.*
>
> *Blackwell-gate and Hound-gate form the principal seats of disease. In the autumn of 1846 I attended upwards of 200 cases of typhus. In these localities a common cold rapidly runs into fever, whereas in other healthy situations it would not do so.*
>
> *But one of the worst scenes I ever witnessed was in Punch Bowl-yard.*
>
> *These localities are generally disgustingly filthy.*

> *In the town there have been 89 deaths from diarrhoea and dysentery between 8th of August and 3rd November* (1850).

From Piper's statement it appears that the waterborne diseases were merely following the natural profile of the water table. As residents drew water they contacted the disease. If the seat of the disease was within the same area the track was bound to be similar.

**The River Skerne**

The condition of the River Skerne was examined by Ranger, Mr T H Jackson, surgeon in his evidence on the character of the disease prevailing in the town, observed:

> *I attribute the unhealthy state of the town, in some localities, in a great measure, to the condition of the Skerne, which is the receptacle for all the sewage of the town and refuse from dye-houses; the overflow of water from the river, and the dampness of the town generally.*

The Rt Rev Dr Hogarth, Roman Catholic Bishop, from personal observation, states:

> *In hot weather, such is the state of the Skerne, that the water, from its stagnant state, appears quite green, and emits an exceedingly offensive smell. The accumulation of all kinds of filth and refuse, animal and vegetable, is very great, but varying in different portions of the year.*

The statements give a graphical testimony of the condition of the water in the River Skerne and confirm its total unsuitability for washing and drinking purposes.

Thresh (1896) commented on two epidemic outbursts of typhoid fever which had occurred in the Tees Valley in September/October 1890, and January/February 1891. These prompted the Local Government Board to appoint Dr Barry to investigate the cause(s).

He found that the majority of cases (99% of 1463) were in the towns of Darlington, Stockton and Middlesbrough and some neighbouring communities. After investigation, Barry concluded the source of the disease was the drinking water obtained from the River Tees and stated it was *utilised as a common sewer*.

The views expressed by the Rt Rev Dr Hogarth appear to be supported by Longstaffe (1854) in his reference to Daniel Defoe's visit to Darlington. At that time (1727) and until a very recent period, the river was wide and shallow and formed a vast morass along its banks on the eastern side. Spencer (1862) records *Rushes used to grow luxuriantly in the River Skerne, where they were cropped for conversion into matting and chair seats.*

The accounts of the Tees and Skerne indicate that the watercourse would not have provided sources of clean wholesome water. In earlier times when populations were not as concentrated or as large, the quality of river water was still likely to be significantly less than the natural spring supply, since effluent and animal waste would have migrated either indirectly or directly into the rivers.

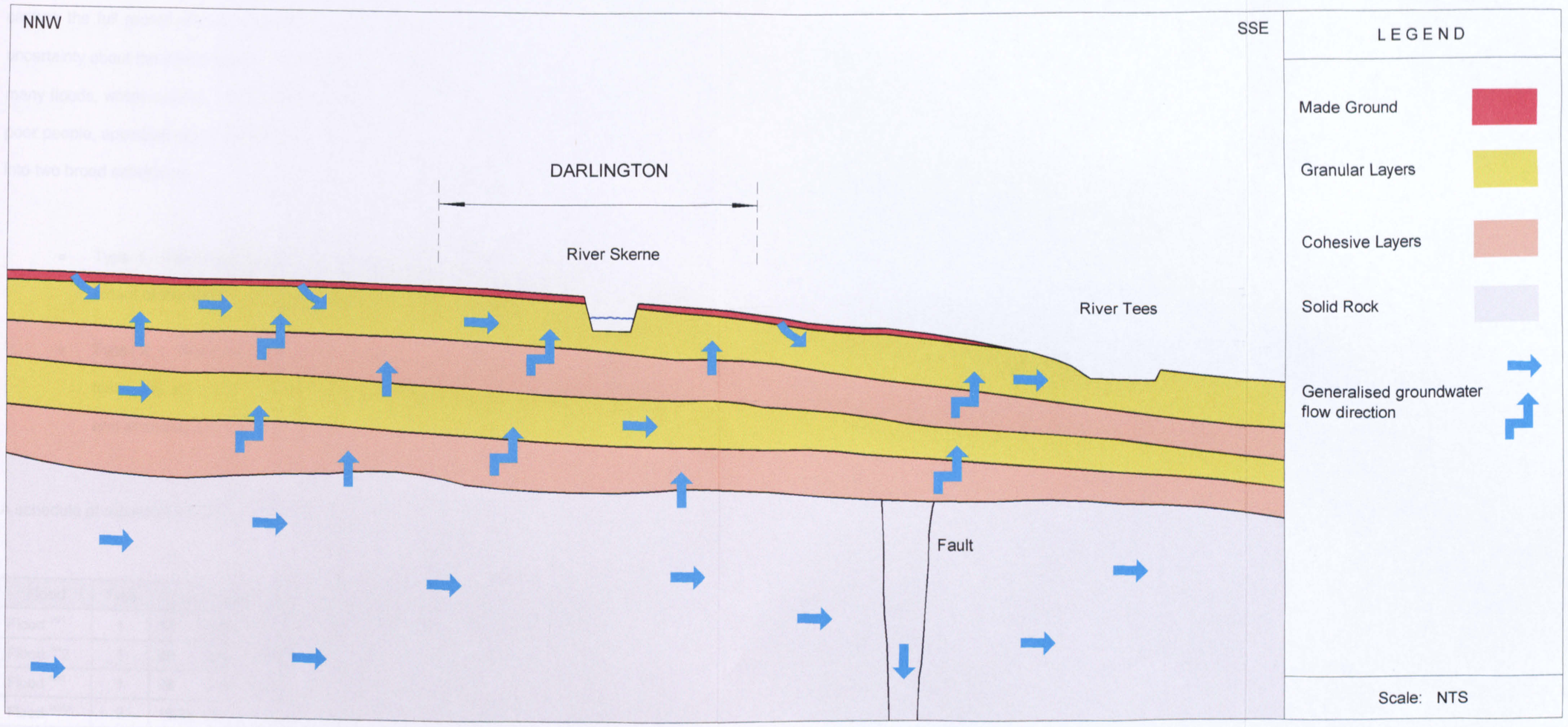



Figure 7.3 - Conceptual Model of Groundwater Flow in the Darlington Area

# 8.0 THE RIVER CORRIDOR

From the evidence collected during this study, it is apparent that it has been impossible to capture the full record of flooding events on the River Skerne. Indeed, there is some uncertainty about the precise date of some floods actually recorded. It is remarkable that many floods, which certainly must have deluged homes thereby causing untold misery to poor people, appeared not to be newsworthy. Of the floods recorded, they appear to fall into two broad categories:

- Type 1 : Recorded events but an absence of tangible evidence as to the extent of the flood.
- Type 2 : Recorded events, sometimes newsworthy, but with unwitting testimony, supported by technical data from various sources, when combined and analysed can define the extent of flooding.

A schedule of recorded flooding events, although incomplete, is given in Table 8.1.

| Flood | Type | Date | Flood | Type | Date |
|---|---|---|---|---|---|
| Flood [1771] | 1 | 17 Sept 1771 | Flood [1933] | 2 | 27 Feb 1933 |
| Flood [1852] | 1 | 29 Sept 1852 | Flood [1941] | 2 | 26/27 Feb 1941 |
| Flood [1856] | 1 | 29 Sept 1856 | Flood [1946] | 2 | 1946 |
| Flood [1875(1)] | 2 | 19/20 Oct 1875 | Flood [1947] | 2 | 20 Mar 1947 |
| Flood [1875] | 2 | 14 Nov 1875 | Flood [1948] | 2 | 11 Jan 1948 |
| Flood [1876] | 1 | 21 Dec 1876 | Flood [1949] | 2 | June 1949 |
| Flood [1880] | 1 | 28 Oct 1880 | Flood [1950] | 2 | 23 Nov 1950 |
| Flood [1881] | 1 | 10 Mar 1881 | Flood [1951] | 1 | Nov 1951 |
| Flood [1886] | 1 | 6 Nov 1886 | Flood [1959] | 2 | 22 Jan 1959 |
| Flood [1900] | 1 | 27 Oct 1900 | Flood [1963] | 2 | 6 Mar 1963 |
| Flood [1903] | 2 | 9 Oct 1903 | Flood [1967] | 1 | 6 Nov 1967 |
| Flood [1924] | 2 | 1 June 1924 | Flood [1978] | 2 | 28 Dec 1978 |
| Flood [1928] | 1 | 13 Jan 1928 | Flood [1979] | 1 | 29 Mar 1979 |

Table 8.1 - River Skerne : Summary of known Flooding Events

Accepting that in all probability the schedule provided above is incomplete, nevertheless conclusions can be drawn in respect of the 'flooding season' and the 'frequency of flooding' on the River Skerne. It will be noted that the majority of floods occur during the winter months of September to March with only 12% occurring during June in the summer. The flooding frequency is variable and is illustrated by the histograms given in Figure 8.1

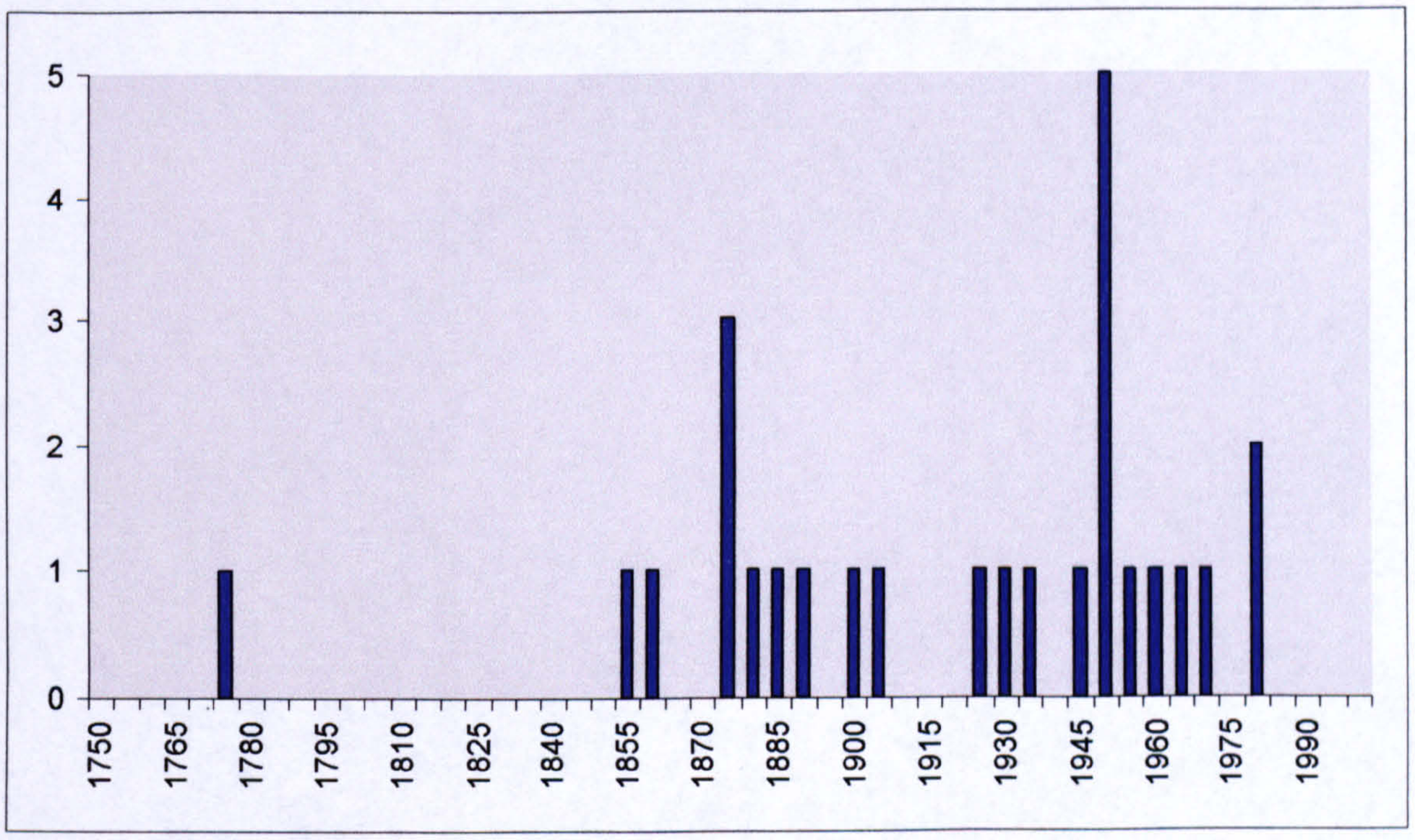



Figure 8.1 - River Skerne : Flooding Frequency

A comparison of the magnitude of Type 2 floods is given at Table 8.2.

| Station | Bridge | | Chainage | | Levels [m] | | | Flood 1875 | Flood 1903 | Flood 1933 | Flood 1941 | Flood 1946 | Flood 1947 | Flood 1949 | Flood 1960 | Flood 1969 | Flood 1963 | Flood 1978 | Design Flood 1982 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface | Soffit | ft | m | Bed | Embankment | | | | | | | | | | | | | |
| | m | | | | | L Bank | R Bank | | | | | | | | | | | | |
| Oxeneyfield Bridge | | | -15320 | -4670 | 26.37 | 30.85 | 30.85 | | *31.16* | | 31.16 | | | | | | | | |
| Field, at Blackbanks Ho | n/a | n/a | | | | | | | *31.44* | | 31.44 | | | | | | | | |
| South Park Weir | n/a | n/a | -1595 | -486 | 33.82 | 35.75 | 35.75 | | *35.34* | | | | | | 35.34 | 35.14 | | | 35.14 |
| Geneva Road Bridge | 38.34 | 37.40 | 0 | 0 | 33.83 | 34.96 | 34.96 | | 35.79 | 35.47 | | | | | 35.66 | 35.42 | 35.78 | | 36.15 |
| Footbridge | | | 545 | 166 | 33.77 | 35.30 | 35.08 | | *36.06* | | | | | | 35.75 | 35.66 | | | |
| Polam Bridge | 36.88 | 36.27 | 1921 | 585 | 33.74 | 35.78 | 35.60 | | 36.52 | 35.85 | | | | | 36.04 | 35.94 | | 36.45 | |
| Victoria Road Bridge | 38.89 | 38.10 | 3421 | 1043 | 34.96 | | | 37.40 | 36.97 | 36.37 | | | | | 36.25 | 35.97 | 36.18 | 36.76 | 36.58 |
| Leadyard Bridge | 37.89 | 37.37 | 4243 | 1293 | 35.11 | | | 38.22 | 37.22 | 36.89 | | | | | 36.74 | 36.82 | 36.94 | | 37.12 |
| St Cuthbert's Bridge | 38.86 | 37.95 | 4721 | 1439 | 35.39 | 38.86 | 38.86 | 38.28 | 37.70 | 36.99 | | | | | 36.94 | 36.88 | 37.09 | 37.08 | 37.37 |
| Priestgate Bridge | 37.98 | 37.58 | 5106 | 1556 | 35.11 | | | 38.44 | 37.48 | 37.23 | | | | | 36.58 | 37.34 | 37.28 | | 37.46 |
| East Street Bridge | 38.62 | 37.86 | 5310 | 1618 | 35.57 | 38.53 | 39.23 | 38.71 | *37.50* | 37.34 | | | | | 37.21 | 37.49 | 37.43 | | 37.61 |
| Russell Street Bridge | 39.93 | 39.32 | 5754 | 1754 | 35.81 | 39.90 | 39.62 | 39.93 | 37.60 | 37.65 | 37.56 | | | | 37.49 | 37.73 | 37.64 | | 37.89 |
| Weir | n/a | n/a | 5824 | 1775 | 37.16 | 38.19 | | | 37.64<br>39.43 | 39.07 | | 38.81 | 39.10 | | 38.97 | 38.95 | 39.01 | | |
| Chesnut Street Bridge | 40.90 | 40.08 | 6530 | 1990 | | 40.75 | 40.75 | | 39.58 | 39.26 | | 39.11 | 39.21 | | 39.16 | 39.14 | 39.26 | | 39.62 |
| Cocker Beck | n/a | n/a | 7115 | 2169 | 37.95 | 40.84 | 40.17 | | *40.32* | | 41.09 | 39.50 | 40.08 | | 39.82 | | | | 40.11 |
| John Street Bridge | 41.03 | 40.39 | 7583 | 2311 | 38.16 | 40.29 | 41.54 | 41.39 | 41.06 | 40.73 | 41.01 | 40.00 | 40.65 | | 40.23 | 40.45 | 40.63 | 40.74 | 41.06 |
| Main Line Railway Bridge | 51.27 | 49.62 | 8275 | 2522 | 39.01 | 41.24 | 42.61 | 41.61 | *41.30* | | | | | | 40.54 | 40.54 | | | 41.34 |
| Albert Road Bridge | 47.00 | 45.96 | 8701 | 2652 | 39.35 | 41.15 | 40.57 | | *41.55* | 41.01 | | | | | 41.01 | 40.93 | | | |
| Forge Railway Bridge | 53.46 | 51.82 | 10515 | 3205 | 40.48 | 41.51 | 41.51 | | *42.68* | | | | | | | 42.06 | | | |
| Five Arches Bridge | 53.55 | 52.75 | 10940 | 3335 | 41.09 | 41.51 | 41.51 | | *42.75* | | | | | | 41.67 | 42.15 | | | |
| Haughton Bridge | 44.38 | 42.55 | 15192 | 4630 | 40.60 | 43.62 | 42.46 | | *43.36* | 42.82 | 43.14 | | | 42.52 | | | | 43.34 | |
| Great Burdon Bridge | 46.79 | 45.50 | 20293 | 6185 | 42.40 | 46.63 | 46.63 | | *45.19* | 44.65 | | | | 43.59 | | | | 44.24 | |

Table 8.2 - River Skerne : A Summary of Type 2 Recorded Floods

From the information gathered, it should be noted that the River Skerne has been subject to frequent flooding with consequent damage to land and property. Since 1875, at least twenty six 'out of bank' floods have occurred, twelve of which are known to be of similar magnitude. One exceptional storm on 14 November 1875 led to a flood generally 1.25m higher than those preceding, resulting in damage to about 750-800 houses in Darlington.

In the report published in the Northern Echo dated the 18 November 1875 - The Recent Floods, Darlington, Distribution of Coals it was stated:

> *Before the distribution commenced, Mr Hudson Reah, the surveyor, together with his staff, made a thorough survey of the whole area covered by the flood, and coals either have been or will be led to every house within the limits marked out on that survey.*

No trace of the survey has been found and a search of the Darlington Public Library revealed that Council Minutes had only been maintained since 1896. Scrutiny of the Borough Engineer's Drawing Archive also failed to yield any evidence.

There are many references within the Northern Echo articles from the 22 October to the 18 November 1875 to the extent of the flooding. Fordyce (1857) gave supplementary information about the extent of the flood.

It is suggested that Mr Hudson Reah's survey of 1875 could be reproduced from this information, if not in whole then in substantial part; however, no map of Darlington exists for 1875. The only maps available for scrutiny were:

- First edition of the OS plan of 1855, at a scale of 1:2500.
- The 1896 edition of the OS plan at a scale of 1:2500.

The latter plan shows that substantial development took place during the 41-year period spanning the two editions. The development was to both the north and south of the 1855 built-up area and within the broad river corridor.

For the flood of 1875, the flooding statistics provides the following information (Table 8.3);

- names of streets within the broad river valley between John Street and Victoria Road which are known to have existed in 1896.
- named streets known to have flooded in 1875 as confirmed by newspaper articles.
- adoption dates, as entered in the Highway Register.
- estimates of the number of houses in the named streets and those flooded.

| Location and Street | Recorded In Newspaper | Date of Highway Adoption | Estimated No | |
|---|---|---|---|---|
| | | | In Street | Flooded |
| **North Embankment:** | | | | |
| Westbrook Villas (Cocker Beck) | ✓ | - | 26 | 26 |
| John Street | ✓ | 1879 | 25 | 6 |
| Lambton Street | ✓ | 1879 | 18 | 5 |
| Leadenhall Street | x | 1879 | 12 | 4 |
| Wooler Street | x | 1879 | 31 | 2 |
| Oxford Street | x | 1879 | 38 | 5 |
| Peaceful Valley | ✓ | 1879 | 5 | 5 |
| Chesnut Street | x | 1879 | 22 | 0 |
| Hill Street | x | 1879 | 8 | 0 |
| Garden Street | x | 1879 | 23 | 0 |
| Bridge Row (Stonebridge) | ✓ | <1834 | 9 | 6 |
| Leadyard | ✓ | - | 1 | 1 |
| Lucks Square | x | - | 17 | 17 |
| School Buildings | ✓ | - | | |
| **South Embankment:** | | | | |
| Valley Street | x | - | 31 | 31 |
| Russell Street | x | - | 14 | 11 |
| Mount Street | x | 1886 | 17 | 8 |
| Freemans Place | ✓ | <1834 | 30 | 5 |
| Clay Row | ✓ | - | 61 | 61 |
| Princess Square | x | - | 7 | 6 |
| Brunswick Street | x | 1879 | 47 | 17 |
| Bowes Street | x | 1879 | 14 | 14 |
| Tannery 1 | ✓ | - | 6 | 6 |
| Tannery 2 | | - | 4 | 4 |
| Church Street | ✓ | - | 24 | 24 |
| Chapel Street | ✓ | - | 19 | 19 |
| ? Street | x | - | 8 | 8 |
| Skerne Row | x | - | 9 | 9 |
| Backhouse Street | ✓ | 1900 | 53 | 53 |
| Cross Street - Backhouse/Park Street | x | - | 13 | 13 |
| Park Street | ✓ | 1884 | 100 | 100 |
| Cross Street - Park Street/Park Place | x | - | 15 | 15 |
| Park Place | ✓ | 1884 | 102 | 102 |
| Hird Street | x | - | 8 | 8 |
| Swan Street | x | 1881 | 35 | 35 |
| Model Place | ✓ | 1884 | 78 | 78 |
| Hargreave Terrace | x | - | 22 | 22 |
| Victoria Road | ✓ | - | 22 | 22 |
| Fields to the Park | ✓ | n/a | | |
| **Total Number of Houses Flooded** | | | | 722 |

Table 8.3 Flood [1875] : Flooding Statistics

Figure 8.2 shows a composite plan of part of the town within the Skerne Valley. The OS 1855 plan has been adopted as the base, shown red, with additional development up to 1896 shown green. By using this information and that tabulated in Table 8.3 the following conclusions were drawn;

- a reasonable assessment of the state of development in 1875.
- the extent of a provisional Flood 1875 flood plain.

From Table 8.3 it will be noted that the provisional total of houses flooded is estimated at 722. This figure appears to compare well with the range 750-800 quoted in the Northern Echo, dated Thursday 18 November 1875. Accepting the newspaper figures, the derived value has an error range of between -4% to -10%. However, caution must be exercised in the case of the validity of the composite plan. It is known that many 'back to back' houses existed during this period and two dwellings would have been represented by a single block on the plan. It is possible to identify many such houses from the 1855 OS plan but the 1896 edition is not to the same level of detail. Consequently, it is likely that many more 'back to back' properties were built within the flood plain from 1855 to 1875 because of their cheapness. Furthermore, there are several yards, squares and tanneries within the provisional flooding envelope. Many small buildings are shown on the composite plan; however, it is not possible to be precise about the number of dwellings affected.

The estimate of 722 is on reflection, probably an understatement of the actual numbers involved. Consequently the figures quoted in the Northern Echo appear to be a reasonable assessment.

Using the information from the newspaper articles and the composite map an interpretation of Reah's original survey (1875) is given in Figure 8.2.

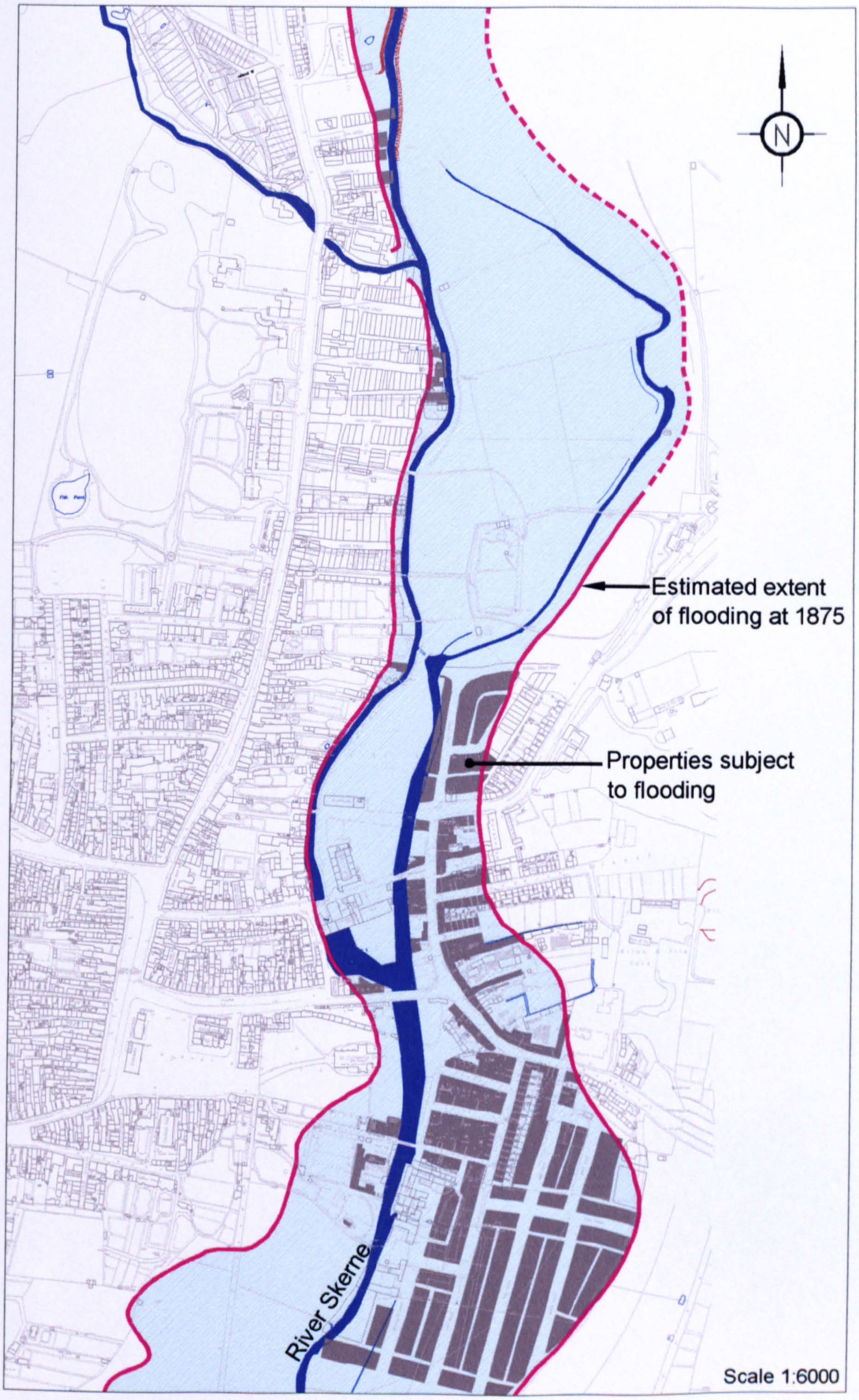



Figure 8.2 - Reconstruction of Reah's Survey 1875

The reconstruction of Reah's survey appears to correlate well with the data retrieved from Harrison's drawings (1876) and the Northern Echo, but is at variance with Archer's (1992) interpretation of the extent of flooding in November 1875 (Figure 8.3).

Figure - 8.3 - Archer's (1992) Plan of Flood [1875]

Examination of the twentieth century floods shows that Flood $^{1903}$ was the most severe, although there is a relative consistency of the group. Flood $^{1903}$ column is highlighted in yellow in Table 8.2 with recorded values given in normal type and estimated values in italics. When compared against Flood $^{1875}$, the column being highlighted in green, the severity of the flood is apparent. In general this flood was up to 1.20m higher than Flood $^{1903}$.

The information collected in the late nineteenth and twentieth centuries suggests that the River Skerne's flooding behaviour has been curtailed to a norm level of Flood $^{1903}$. None of the man-made improvements, however, have demonstrated that the Skerne has been mastered, nor have these engineering works eliminated or contained the threat of flooding within the river valley.

The crucial issue is: what height was attained by previous unrecorded floods?'

Archer (1992) provided some very valuable information about early floods on the River Tees from 1356 to 1875 which may have some relevance to the River Skerne within its catchment (see Table 8.4).

| Date | Comment |
|---|---|
| 1356 | After a great flood, *'the good men of Croft'* were granted an allowance for repairing the bridge. |
| 1531 | Water undermined *'the grete bridge at Croft'*. |
| 1624 | A winter flood. |
| 1638 | Repairs to *'Yarum'* bridge - assumed to be a consequence of a major flood. |
| 1684 | A winter flood, almost certainly due to melting snow. |
| 1640/88 | Several further floods were noted by Christopher Sanderson. |
| 1753 | A major event, affecting Stepleton, Croft, Neasham and Yarm. |
| 1761 | A major event known to have affected Yarm. |
| 1763 | A major event known to have affected Yarm. |
| 1770 | A major event known to have affected Yarm. |
| 1771 | The Great Flood (Flood [1771]) |
| 1783/89 | The Church at Yarm was flooded. |
| 1794 | Flooding at Stockton - even higher than Flood [1771] |
| 1815 | Flooding from snow melt. |
| 1822 | Tees over topped its banks at Croft bridge. |
| 1828 | Flooding of agricultural land. |
| 1829 | Floods at Middleton, Yarm High Street 6' deep. |
| 1837 | Flooding at Yarm due to rapid thaw. |
| 1852 | Flooding on Skerne, Croft and Neasham. |
| 1856 | Similar event to 1852. |
| 1872 | Yarm flooded following thaw. |
| 1875 | Two floods in quick succession Flood [1875(1)] & Flood [1875] |

Table 8.4 - River Tees : Flooding Frequency (from Archer 1992)

The information illustrates that the River Tees is subject to frequent serious out of bank flooding, adversely affecting settlements along its banks.

The re-engineering and subsequent management of the River Tees, particularly in the upper and lower reaches, have undoubtedly changed its flooding capability; a Flood $^{1771}$ event would be unlikely to have its similar affect.

The combined evidence relating to the flooding of the Tees and Skerne suggests that the height of early history floods were perhaps as high as the Flood $^{1771}$.

The issue then is - is it possible to estimate the effects of Flood $^{1771}$ on Darlington?

Flood levels at Yarm are recorded for both Flood $^{1881}$ and Flood $^{1771}$ at 7.63m OAD and 9.30m OAD respectively, some 1.67 m difference in height.

The method adopted for transferring the flood levels from Yarm to the Skerne Valley at Darlington is by simple approximation. This is based upon the assumptions that;

- the catchments of the Tees and Skerne were totally saturated.
- the flooded cross sectional areas of the Tees Valley for Flood $^{1881}$ and Flood $^{1771}$ are in direct proportion to those on the Skerne Valley.

The actual procedure is as follows;

- establish the cross section of the Tees Valley at Yarm through the 'Old Town Hall'. The topographical information for this exercise was kindly provided by the Environment Agency on an Excel (.xls) format.
- levels for floods, 1903 (the control flood at Darlington), 1881 and 1771 were plotted on the cross-section.
- flood areas representing each flood were calculated in A $^{1903}$, A $^{1881}$ and A $^{1771}$.

- the ratios, $A^{1903}$: $A^{1881}$ and $A^{1903}$: $A^{1771}$ were calculated.

- cross sections for the Skerne Valley were constructed at the strategic bridge locations given at Table 8.2 based upon the Contours $^{1852}$.

- equivalent flooded areas, for each cross section for $A^{1903}$ were calculated and the appropriate ratio was used to obtain $A^{1881}$ and $A^{1771}$, then plotted on each cross section.

- the information, in respect of the width of the floods, was transferred to the contoured map of Darlington town centre given at Figure 8.4. Additionally, the limit of the 1875 flood plain has been superimposed on the map.

From Figure 8.4 it will be noted that the estimated flood plain of Flood $^{1771}$ and Flood $^{1875}$ are almost coincidental. Their tracks are so close it has been concluded that these two separate floods would have had a similar effect on Darlington, assuming that Flood $^{1771}$ actually occurred.

The evidence suggests that severe flooding events on the Skerne were not rare. Consequently, the likelihood is that the estimated flood plain of 1771 and 1875 would define the absolute limit of development on the western bank of the Skerne of any early settlement.

Hydrological data were collected for the reaches both downstream and upstream of the town centre area, although in less detail. Adopting the topographical data used by the Wear and Tees River Board in relation to Design Flood $^{1952}$, a longitudinal section of the River Skerne was drawn between the confluence with the Tees to Aycliffe Bridge - given at Appendix 31. The following information is given on the longitudinal section;

- between the River Tees and Aycliffe Bridge;

⇒ hydraulic gradient of Design Flood 1952.

- between Victoria Road and John Street;

⇒ suggested hydraulic gradients for Flood [1771] and Flood [1881].

⇒ hydraulic gradients for Flood [1875] and Flood [1903].

Using this information and the current topographical data, a small scale indicative flood plain map was produced for the whole reach; this is given at Figure 8.5.

No attempt was made to extend the most severe flood plain limits beyond Russell Street Bridge. However, incomplete information relating to the extent of flooding within the Skerne Valley arising from Flood [1949] was captured. The resultant flood plain between Aycliffe Railway Bridge (NZ 428617 522573) and the Main Railway Line Bridge (NZ 429727 516071) is shown at Figure 8.5. Also shown on the same figure is the extent of flooding on the Tees, in the region of the Skerne confluence (NZ 428923 510092), near Hurworth Place occurring as a result of Flood [1950]. Additionally the 1968 flood plain for the village of Neasham is also shown. Since 1968 the Environment Agency has constructed extensive flood defence works on the River Tees embankments at strategic points.

Despite the incomplete nature of the flood data available for the Skerne upstream of Russell Street Bridge (NZ 429177 514811), it is evident from inspection that Flood [1968] breached the design parameters of Design Flood [1952]. Consequently, it would appear that many houses built within the natural flood plain are without adequate flood defences.

The derived flood plain maps have further implications for the modern settlement of Darlington, since vast tracts of commercial and residential property lie within the town centre flood plain. Of particular importance is the vulnerability of the emergency planning services command centres at the Town Hall, Police Station and Fire Station, all of which are situated within the 1875 flood plain.

The outcomes of this exercise differed substantially from the indicative flood plain produced by the Environment Agency. After discussions with the Agency, it has accepted the interpretation of this research. Furthermore, the Durham and Darlington Emergency Planning Unit has also accepted the revised flood plain limits and has incorporated them, without modification into the Darlington Emergency Plan. The criterion set down in Table 8.4 now forms the basis of responses to flooding in Darlington by the Unit.

Many attempts have been made to re-engineer the River Tees and River Skerne to overcome a problem of navigation, water supply and flooding. Archer (1992) reported that between 1864 and 1877 seven million tons of material were removed from the lower reaches of the Tees. Thereafter, for several decades, dredging was about 400,000 to 500,000 $m^3$ per annum. Six reservoirs were built on the upper reaches at Hury (1894), Blackton (1896), Grassholme (1915), Selset (1960), Balderhead (1965) and Cow Green (1970), with a total storage capacity of about 88 million $m^3$. The river bed of the Skerne has been systematically and repeatedly regraded between 1876 and 1966.

Archer (1992) further recorded that floods on the Tees of 1753, 1783 and 1822 reached similar heights to that of 1881, but only the flood of 1771 was unequivocally higher throughout it length, some +1.67 m difference in peak flow at Yarm.

Information collected on 'modern' flooding events suggest that although engineering works may have normalised the River Skerne to a level associated with Flood $^{1959}$, none of the technical improvements has yet demonstrated that flooding events on the Skerne have been mastered.

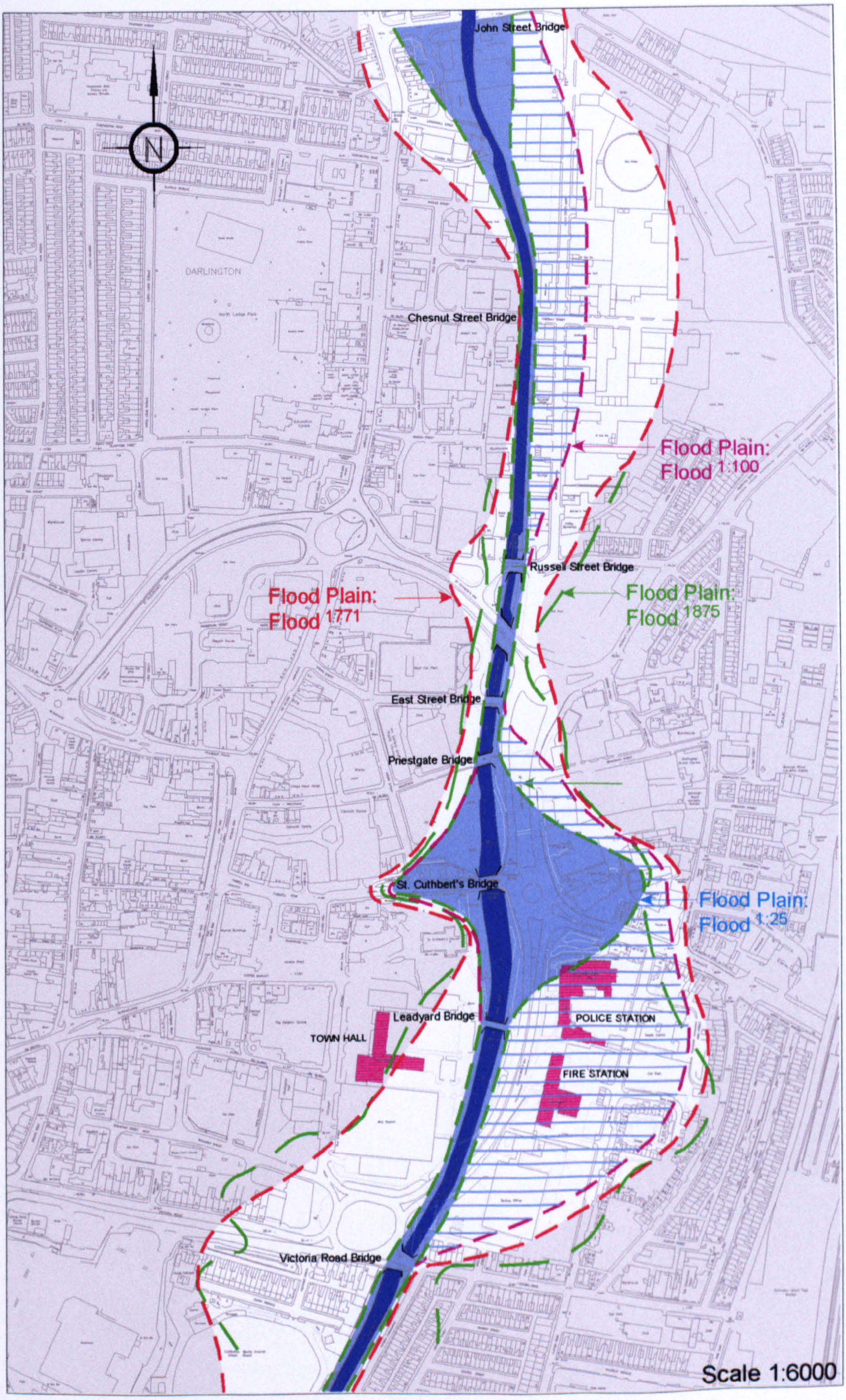



Figure 8.4 - Darlington: Estimated Flood Plains

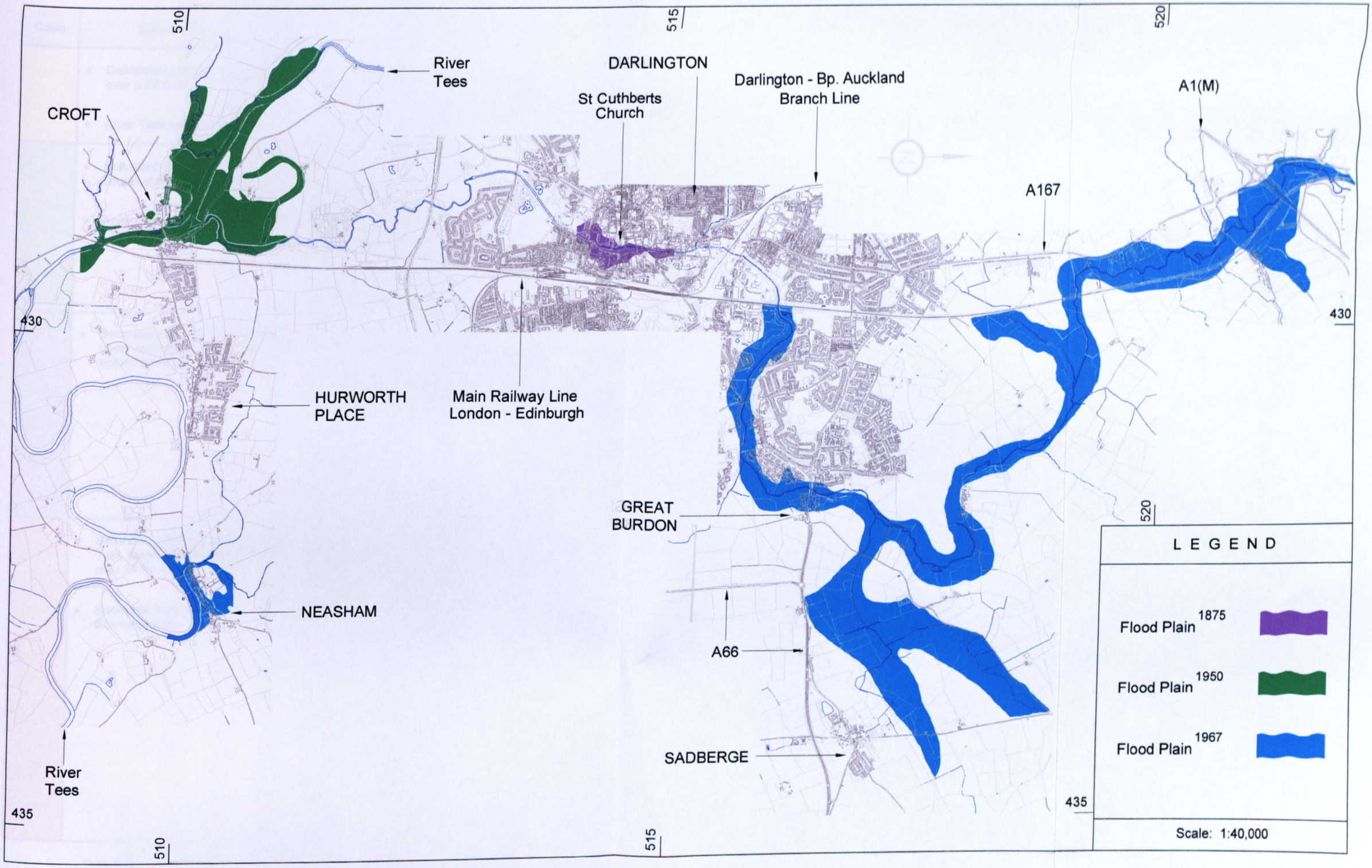



Figure 8.5 - Composite Indicative Flood Plains for Tees and Skerne

| Code | Meteorological Conditions | Consequence |
|---|---|---|
| | • Catchment subject to rainfall of <50mm over a 24 hour period.<br><br>• River Tees catchment not affected. | River within bank.<br><br>Localised flooding. |
| | • Saturated catchment subject to about 50mm of rainfall over 24 hours.<br><br>• River Tees catchment not affected. | River out of bank 1 in 20 year event.<br><br>Localised flooding.<br><br>Emergency Services required.<br><br>Property damaged. |
| | • Saturated catchment of both Skerne and upper reaches of River Tees subject to about 50mm of rainfall over 24 hours. | River out of bank 1 in 50 year event.<br><br>Extensive flooding.<br><br>Property damage.<br><br>Roads blocked.<br><br>Emergency Services required. |
| | • Saturated catchments of both Skerne and Tees subject to rainfall greater than 50mm over 24 hours.<br><br>• Snowmelt from either upper Tees or Skerne or both. | Catastrophic flooding of the Skerne Valley.<br><br>1:500 year event.<br><br>Extensive flooding.<br><br>Property damage.<br><br>Road blocked/damaged.<br><br>Threat to life.<br><br>Emergency Services required.<br><br>Property evacuated. |

Table 8.5 - River Skerne - Suggested Responses to Flooding Criterion

# 9.0 TOWN LAYOUT

Darlington town centre appears, by the grid pattern of the plots, to have a planned layout (Figure 9.1). The plot boundaries correspond exactly to the site boundaries given on the OS first edition map of 1856 and the dimensions of those plots, assumed to be the original burgage plots, vary according to location. They have a definite symmetry and are generally rectangular in shape with the smallest dimension on the street frontage. Some plot boundaries seem to follow a reversed S-shaped curve of a former ridge and furrow pattern of open fields. Hindle (1990) suggested this was to avoid the necessity to level the original site.

The actual size of the plots is in the order of 1.5 poles (25 ft ÷ 16.5 ft) (7.55m) wide and 11.5 poles (190 ft ÷ 16.5 ft) (57.85m) deep. The burgage plots at Salisbury (Hindle 1990) were 3 x 7 poles (15.10m x 35.21m) and those at Stratford-upon-Avon (Slater 1987) were 3.5 x 12 poles (17.61m x 60.36m) (about a ¼ acre). It should be noted that there is confusion over the use of the words of 'pole' and 'perch' which are often taken to be the same linear measure, but the latter refers to area in purist terms. Whereas the depth dimensions of the Darlington plots are within Salisbury and Stratford range, the widths are only about half their values. Consequently, it may be that the plots as drawn are second generation sub-divisions of the original burgage plots.

The grid pattern appears to commence at the Blackwellgate/Houndgate junction and continues along both sides of Skinnergate as well as High Row. The size of the plots, however, changes immediately north of the north-south aligned plots and are larger. Similarly, the layout around the Priestgate block appears to be larger still. If this distribution is similar to Ludlow, it can be concluded that the smallest plots are in the town centre and the larger ones along the main north-south road of Skinnergate. Furthermore, the distribution of the plot sizes may indicate the date when areas were laid out (Hindle 1990).

Figure 9.1 clearly shows burgage plots fronting a central open area at Blackwellgate, and perhaps this was the location of the original market place. The present market place in front of St Cuthbert's Church is likely to be contemporaneous with the church (1194). To the north of Skinergate/High Row block of plots is another large open area which resembles the shape of a linear market place. Perhaps this was set up outside the then town boundaries as a rival market.

Because of time constraints this section of the present study is incomplete and so raises more questions than it answers, including;

- could the original settlement have been located around the open area in Blackwellgate? Certainly, the burgage plot pattern and the plot sizes do not preclude this possibility. If so, was this area the original market place?

- could a church have stood at the east end of this 'market place' and been demolished and the site built over? Bishop de Puiset was allegedly a developer of green field sites (Leyland, M *pers com*). Is it coincidence that the Blackwellgate market place is a similar shape to Bishop de Puiset's new St Cuthbert's Church precincts, including the area of the existing market place? The relationship between the two areas is given in Figure 9.2.

- could the original settlement have been enclosed by the suggested natural boundaries shown orange on Figure 9.1 and perhaps fortified by associated defensive ditches?

All of these issues require further investigation and are quite beyond the scope of this present study.

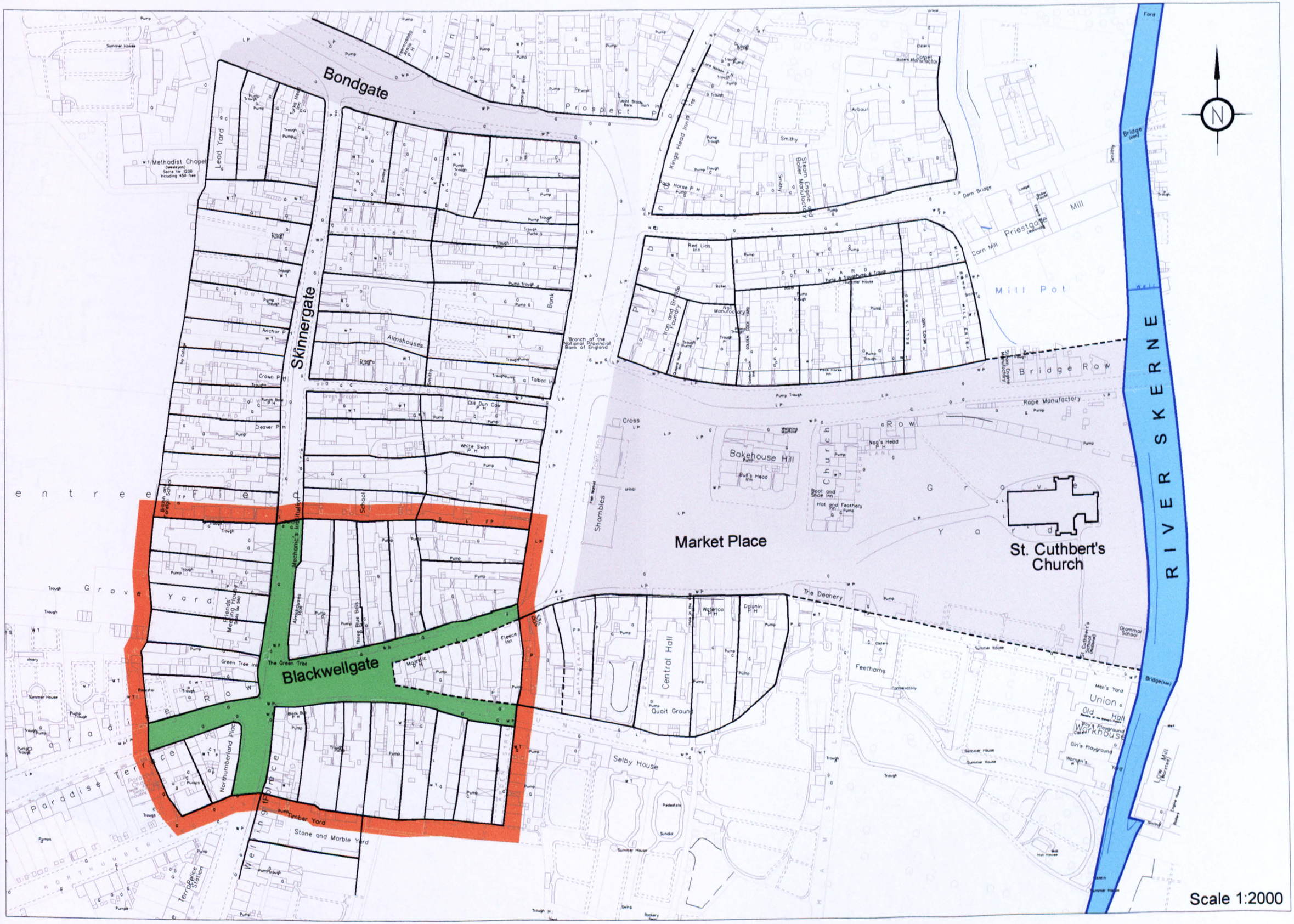



Figure 9.1 - Town Layout

Figure 9.2 - Relationship between 'Market Areas'

# 10.0 - FUTURE DEVELOPMENTS

With the multi-disciplinary approach adopted for this study, several areas of investigation are by the necessity of time constraints incomplete. Therefore, further work is required to gain a greater understanding of the subject.

## 10.1. Geology

As the need arises for site investigation in the Darlington area, this study could be used as a basis to identify areas of poor coverage of existing information. The resultant data could be used to update this unique geological database. In this way the geology models already constructed for the solid and drift could be further refined. Formal partnerships might be established as a national pilot study to assess its value and effectiveness. Partners may include the appropriate government department, British Standards Institute (BSI), BGS, Local Authority, and other industrial representatives. It is likely that the outcome would lead to greater scientific knowledge and ultimately financial savings together with improvements to the national resource.

This study has highlighted the mixed quality of existing retrieval systems in respect of primary data at all levels of the industry. Undoubtedly benefits would accrue if there was a unified standard of recording and capturing data, as demonstrated by this project. It is suggested that the BGS consider such an initiative but government should be encouraged to introduce primary legislation to place a statutory duty on all sectors of industry to deposit all geological data with BGS.

## 10.2. Made Ground

Many areas of contaminated land have been discovered by this study, not only within the made ground zone but also within the drift deposits. By the nature of the investigation of

using only desk-top study techniques, coupled with the fragmented pattern of the boreholes examined, it is suspected that much more land will have been adversely affected. Consequently further controlled studies targeted to identify contaminated land issues could be considered. Since there could be potential impacts on the quality of water supply and the river, together with health and safety issues generally, this may be a matter in which the environment agency may take an interest. Additionally, a case may be made for European funding using the preliminary data available from this study as a basis for an application for a further research project.

### 10.3. Archaeology

This study may have identified a new opportunity to locate accurately areas of high archaeological interest in Darlington. If so, then further investigation is required to assess this hypothesis. Initially potential sites would be best safeguarded by the introduction of an appropriate Archaeological Strategy. The Strategy would need to be adopted by both the Local Planning Authority and the County Archaeological Officer and ideally incorporated into the Darlington Local Plan. Informal discussions with the Local Planning Authority have resulted in a willingness on their behalf to pursue such an initiative. Once adopted, field excavations would validate the hypothesis.

### 10.4. Town Layouts

The analysis of the town layout system is a very large undertaking and is considered to be beyond the scope of this study. A database was set up to capture all relevant data in respect of Dmap [1852]. The fields included the widths, depths and areas of individual plots. It was intended that this information could lead to a detailed analysis of the town layout. The work, however, involved many thousands of measurements but this undertaking was unable to be completed because of time constraints. Only the basic layout could be

determined and this is given in Chapter 9.0. It is considered that this avenue of research could be subject to a separate research study.

## 10.5. Flooding

Figure 8.5 shows extensive flooding of the River Skerne Valley from the town centre to Aycliffe Bridge. Within the built-up area of Darlington, many recently constructed commercial and residential developments appear to be located within the Flood [1967] floodplain. This study suggests that the town is subject to much more damaging floods and even more properties would therefore be vulnerable. In order to make accurate predictions on the number of properties affected, and the degree of severity of damage, precise surveying of the river valley, together with the floor levels of the buildings affected, should be undertaken. Once this task is achieved, then risk assessments should follow together with appropriate flood defence measures if needed.

## 10.6. River Corridor

The river corridor presents ample scope for further research projects, including a complete environmental review of all aspects of life within the river and its embankments. Monitoring stations to detect ground-water movements, together with chemical analysis of ground water and soils, could be established to detect the effects of the contamination already identified.

# 11.0 - DISCUSSION

## 11.1. The Geology in General

The library of borehole logs in the public domain at the beginning of this study was limited, estimated at about 20% of the final total. The data collection exercise for this study relied upon the goodwill of those employed in all sectors of the industry and the key to this was personal knowledge and communication with colleagues working for consultants and contractors who held information within their private records. It became evident, however, that a significant amount of information, perhaps up to 20%, had already been permanently destroyed.

In all 1029 borehole records were examined during this study and the summation of the individual drilled lengths equate to almost 20km with about 9km penetrating the solid geology. The maximum depth of a single borehole was 203m. In order to evaluate the cost of the exploratory work a notional Contract Document was produced and priced using competitive rates at Year 2002 base date (Appendix 32). This document was to current industrial standards for both the drift and solid geology together with associated testing and subsequent reporting. This hypothetical site investigation contract was 'tendered' at a total cost of approximately £6.5M. To complete the databases, it would be necessary to produce drawings and mapping but obviously this would be an additional cost. It is acknowledged that this exercise would be impossible to carry out today since many of the borehole locations are no longer accessible because of the presence of buildings and, in many cases, the original land formation is no longer in existence. Therefore, the retrieval of the primary information, albeit an incomplete record, is an invaluable asset. This relatively small study (in relation to a potential countrywide data bank) has demonstrated the potential magnitude of the waste of valuable primary geological information. Recommendations to arrest this information drain are given in Chapter 13.0.

It was observed during the data collection exercise, that some development sites, particularly in town centre and industrial locations, had been drilled on more than one occasion (the maximum was five separate investigations). This came about as a direct consequence of the lack of a central public databank and the perceived need, on the part of developers, for commercial confidentiality. It was also noted that many opportunities had been missed by those responsible for site investigation work. Examples included deep borings terminating in a void within the solid and made ground not proved to natural.

The method of recording geological information across the whole of the industry is less than satisfactory. It would appear that the primary objective of determining the local ground conditions outweighed the need to record accurately the borehole locations (to National Grid Reference) and their ground levels (to Ordnance Datum Newlyn). These spatial attributes were invariably missing, but in the case of ground levels, when given, appeared to have been estimated from the OS plans showing contours at 10m intervals. To determine these attributes would have added to the original cost of the site investigation, particularly in remote rural areas and this consideration may have influenced the scope of investigations.

Through the following generalised process of;

- assigning spatial attributes to each borehole to national referencing systems and codifying each unit of ground encountered, and

- committing the information to electronic databases capable of interfacing with complementary computer packages such as AutoCAD;

it was possible to analyse various outcomes and reach a consensus interpretation of the results.

The interpretation of the solid geology was done in collaboration with the BGS; there were advantages in this approach, including;

- free access to the BGS borehole database.
- BGS have access to a wider database since it holds a significant amount of confidential information from various sources. Whilst this information was not directly used, its involvement can mitigate against misleading outcomes due to limited information.
- an authoritative outcome is more likely.

Through the partnership arrangement with the BGS, a national mining company allowed its records relating to several deep boreholes, previously held on a confidential basis, to be placed in the public domain. Similarly, a local quarrying company released all of its own data to this study. Both were examples of the benefits of collaborative working and the value of personal communications.

Over the life of this study (six years), not surprisingly many factors changed which, in some cases, led to abortive work. Many of these changes focused around the rapid developments in information technology and its ever increasing availability.

In respect of the data collection of the geological information, initially the National Grid co-ordinates were determined by measuring the values directly from the relevant ordnance survey sheets (after the position was finalised). This information was transferred to the appropriate database by keystrokes (1029 x 6 x 2 = 12500) and then subjected to checking via the adopted quality assurance protocol (Chapter 12.0). After this exercise was completed however, access was gained to a graphical information system which also incorporated the relevant OS digital maps. From the computer screen the National Grid co-ordinates were instantly available for any point. Furthermore, the values of eastings

and northings (to two decimal places of one metre, if required) could be directly exported into Microsoft Excel Files (.xls) and then into drawing packages such as AutoCAD. Had this facility been available at the beginning of the study, undoubtedly considerable time would have been saved. Nevertheless, the dual process did serve as an additional and valuable checking exercise.

When capturing the geological information, practical operating decisions were made in accordance with the recommendations of the BSI Code of Practice for Site Investigation. These naturally led to a compromise solution on the extent of data which could be included in the final borehole log. It was unfortunate that not all of the information could be gainfully utilised on this occasion. Whilst there was not full coverage of individual items of data across the scoping area, it would have been useful to record such details as;

- bulk densities
- moisture content.
- shear force values.
- standard penetration results, etc.

Such results would have been of particular value in the town centre area where there is frequent need to have a detailed understanding and knowledge of the soil characteristics. Nevertheless, where the information was available it was noted on the take-off sheets given in Appendix 9. This information is, however, still in manual format.

Every endeavour was made to locate and recover geological information. It would, however, have been very useful if at the beginning of the study, some guidance had been available for typical yardsticks. For example, target numbers for urban and rural areas based upon a national rule of thumb value. On the assumption that say 80% of all original data has been captured, it might appear reasonable, for town centre areas, to assume a

target value of about 550 to 600 boreholes per square kilometre (454 ÷ 0.8/km$^2$). Density estimates for the rural area are perhaps more unreliable, since there is a known high proportion of boreholes which are held on a confidential basis.

The derived borehole referencing system worked well and proved to be flexible enough to manage the whole of the geographical area under consideration. It would, however, require slight modification it is were to be adopted as a universal system.

The use of a proven commercial package for the storage of geological data was successful and allowed large volumes to be managed. In this case, Key Systems' HoleBASE II led to the satisfactory storage of the data and also provided the necessary platforms and interfaces with other systems such as AutoCAD. There was an added value, in that the system was continually updated by the vendor. The nature of the licence agreement included the involvement of a professional user group which, in conjunction with the vendor, also periodically modified and updated the package. It is understood that the practical limit of the HoleBASE II programs is in the order of about 2000 boreholes per project. The range and magnitude of the geological data used to support this study, therefore, are well within its capacity. Having established the geological database, with the goodwill of the industry, it is important that it is continually updated and made available to subscribers.

## 11.2. Archaeology

Since so little is known about the pre-history of Darlington, it is important to identify and protect as appropriate, any remaining archaeological remnants. This study has demonstrated that there appears to be potential to predict, although to a limited extent, where such artefacts may lie. In all the examples cited to validate the hypothesis, the Promoter of the scheme undertook the additional work on a voluntary basis after discussion. If opportunities are not to be missed, then it would appear to be prudent to

rely on a more formal arrangement. After discussions with the Local Planning Authority (LPA) and its archaeological advisors, there is a willingness to incorporate an Archaeological Strategy into the now emerging Local Plan. Such a strategy would allow a managed approach to be taken in accordance with Planning Policy Guidance Note 16 (PPG 16) and the new information highlighted by this study. Advantages would accrue, including proposed development on 'cleared' sites proceeding unfettered, whilst those with potential could be identified in advance of proposals. In the case of the latter, the archaeological investigations could be programmed into the overall development plan and appropriately costed.

Opportunities could be taken by those responsible for planning new site investigations to broaden horizons by incorporating the needs of archaeologists. It would be a relatively simple and cheap exercise to include for additional samples and subsequent testing for archaeological purposes.

It is probable that the most important sites, when discovered, will be located beneath small development sites since the majority of large areas in Darlington Town Centre have already been developed. If this proved to be the case, then the funding of appropriate archaeological work may be an issue. It is possible that these costs could be disproportionate in relation to the overall development costs rendering the project unviable in commercial terms.

If the value of the archaeology is seen to be of benefit, then there is a reasonable argument for the wider community to contribute. To overcome the difficulties with piecemeal development in this respect, there could be merit in the LPA establishing a single trust to fund such work. Government could be encouraged to consider the merits of strengthening planning authorities' powers to raise a levy on developments in historic towns similar to the Percent for Art Scheme. The levies could go into a Community Archaeology Fund and used at the LPA's discretion.

## 11.3. Cartography

The capture of original information relating to the eighteenth century surveys was compiled by traditional hand-drawn techniques. The method worked well enough with the final composite plan (Figure 2.15), achieving good edge matching. This result, however, was due to the accuracy of the original work by the various surveyors. As in the case of the geological information, computer scanning techniques produced at least the same quality results at a fraction of the time.

The use of digitising historic plans and drawings proved to be an extremely useful exercise. The original work was organised to produce a series of GIS layers of information. This allowed greater flexibility in the analysis and interpretation of the data. These maps, in digitised format, will be released into the public domain, thereby making them available for further research and reference purposes.

## 11.4. Topography

Topographical data was the most elusive to capture. The information given at Dmap [1852] appeared to be an unrelated series of floor levels of the buildings. The benchmarks shown were not directly related to each other, nor was the height of the mark relative to floor levels shown. By a series of trial and error exercises, coupled with some cross referencing to the few buildings still in existence, it was possible to decipher the dataset (Figure 5.1).

The most accurate topographical information was found on engineering drawings. Some 8500 drawings were examined from the Borough Engineer's Drawing Archive and data transferred from these onto a database. The resultant composite drawings tied in extremely well with virtually no error at the edges of individual projects. The level of detail and accuracy achieved by this method was very high and worthwhile.

## 11.5. Town Layout

It would appear that the town layout of the existing Darlington Town Centre is of a medieval nature since the grid pattern appears to tie-in with other historic towns which have been carefully studied. Only a limited amount of investigation was possible in this topic but a clear planned town pattern of development has emerged. The core of the old town is relatively small and appears to be centred around an open area presumed to be the original market place. It is located on high ground and above the floodplain.

## 11.6. Flooding

The data in respect of flooding events, its impacts and implications, were in a fragmented form at the beginning of the study. Although a significant amount of the original information has been captured, it is accepted that much has been forever lost. This destruction of primary evidence may have arisen from decisions based on short-term pressures on accommodation or the ever increasing cost-cutting exercises facing firms and organisations. Additionally, mergers, both in the public and private sectors, have resulted in fewer centralised establishments. It is suspected that with each reorganisation, prime documents have been lost because of the need for greater financial efficiencies. Unlike Newton's First Law *Energy cannot be created or destroyed* it is apparent that *Archives can be created and destroyed* but at great expense.

# 12.0 - QUALITY ASSURANCE

This study was undertaken on a part-time basis over a six year period and involved the collection of a substantial amount of alphanumeric data. Original documentation was found in several forms including maps, paper, microfiche and microfilm. Often the primary evidence comprised either first or second generation copies which were sometimes very difficult to decipher with a significant degree of interpretation needed. Much of this required the use and aid of magnification techniques. The magnitude of the Geology and Cartography databases were, for example, 10 Mb and 28 Mb respectively.

Under the guidance notes for the submission of a thesis it was not possible or desirable to submit all of the data collected and the generated information. For example the borehole logs derived from the geological database extend to about 3000 pages of alphanumeric information.

In addition to wishing to achieve the greatest level of accuracy for academic purposes, it is possible that information produced by this study could ultimately be used to make commercial decisions by the construction industry. Consequently, it is important to have a high degree of confidence in this work and hence a self-imposed quality assurance system was utilised to maximise the accuracy of the data and minimise potential errors.

A protocol was devised and consistently applied to all aspects of this study. This checking regime comprised a simple process of repeat activities with time lags between operations and effecting the necessary corrections. The following sequence, in the case of capturing geological data, was strictly adhered to;

- having established the national grid references, ground levels, borehole identity numbers and converted units to metric equivalents, all relevant

information was entered onto Work Sheets (Appendix 10) and OS plans. This was done for each site investigation project.

- data were entered onto the database, logs were printed and alphanumeric information checked against originals. Corrections were made and the draft log printed and filed numerically according to Hole ID with the site investigation project.

- the procedure exercise was repeated as an independent exercise. The results were compared with the outcomes of the first version and amended where necessary after scrutiny of original documentation. The file was then updated with incorrect logs being destroyed.

- the exercise was again repeated.

- the final outcome was accepted as the definitive version.

Finally, the generated outputs have been produced with the benefit of sophisticated computer packages resulting in high-grade outputs. Despite this, it is recommended that measured judgements should still be made when interpreting the outputs from this study.

# 13.0 - CONCLUSIONS

By assembling information from many apparently unrelated sources and combining the resultant data into unified databases, new opportunities arose for investigation. Whilst the mechanisms of achieving this task were an onerous commitment, the study has demonstrated the value of multi-disciplinary working across professional boundaries.

Three key indicators have emerged in respect of predicting the origins of the early settlement, namely;

- town layout,
- water supply, and
- relationship with the river.

Within the medieval core of the old town lies a small area of distinctive burgage plots which are centred around an open area which could have been a former market place. This site coincides with the best spring water supply, which is virtually at or just below, natural ground level. Additionally, the site is located on the gentle western sloping embankments of the River Skerne and above the high-tide level of the worst known flood.

The immediate tangible achievements can be summarised;

- the BGS have acknowledged the value of this study in respect of the solid geology and have revised the published geological map of Darlington as a direct result.
- new geological maps have been produced for the drift sequence within both the Darlington Town Centre area and the River Skerne Corridor. This

section of the study has yielded a greater understanding of areas of contamination and the mechanisms for its distribution within the underlying strata.

- protocols have been identified for archaeological investigation. This initiative has directly led to the acceptance of an Archaeological Strategy, based on the recommendations of this study, into the Local Planning Authority's statutory Local Plan.

- by identifying the likely extent of the River Skerne flood plain, areas of vulnerability to flooding have become apparent. Whilst further validation is required on this issue, the Environment Agency has allocated a greater priority to investigating the characteristics and behaviour of the River Skerne. Important consequences (to the community) will follow and should include;

  ⇒ a programme of capital investment to introduce appropriate flood defence measures.

  ⇒ reasonable assessment of the risk and impact of flooding on existing property.

  ⇒ the introduction of appropriate development control policies, incorporated into the Local Planning Authority's statutory Local Plan. It is anticipated that mitigation works will be identified and quantified in the case of new development proposals within the flood plain.

- new procedures have been developed from this study which have been incorporated into the Durham and Darlington Emergency Planning Unit's Emergency Plan as its response to serious flooding events in Darlington.

Despite the initial achievements of this study, much more work is needed on every aspect considered. A programme of continuous improvement and review is required to establish

even greater understanding of individual and related disciplines. Without broad acceptance of the general principles of public-private partnerships across the political and industrial spectrum, it is difficult to imagine that voluntary parochial codes will achieve the objectives advocated.

Consequently, Government should be encouraged to introduce primary legislation to facilitate these concepts. In so doing, scientific knowledge will grow immeasurably, coupled with a corresponding increase in wealth of national resources.

My concluding thoughts are that if collaborative working to unified codes were unilaterally embraced, many scientific mysteries currently evading detection could be explained.

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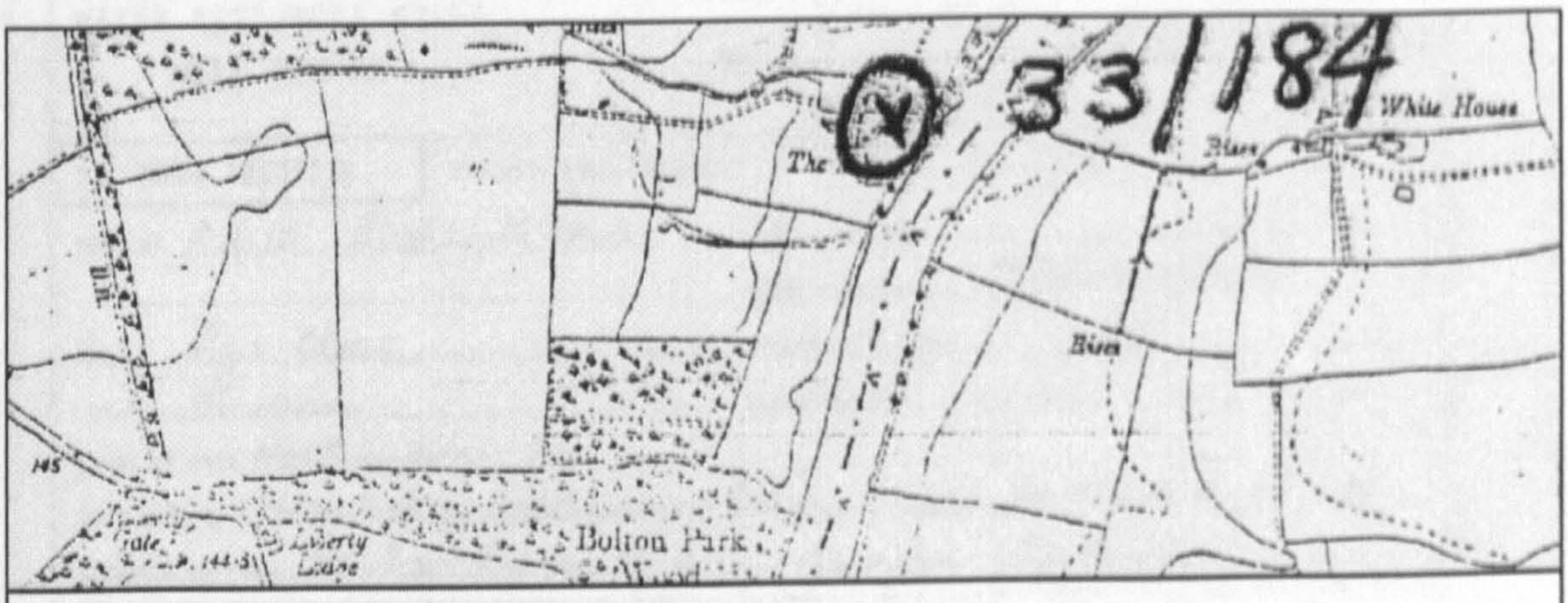
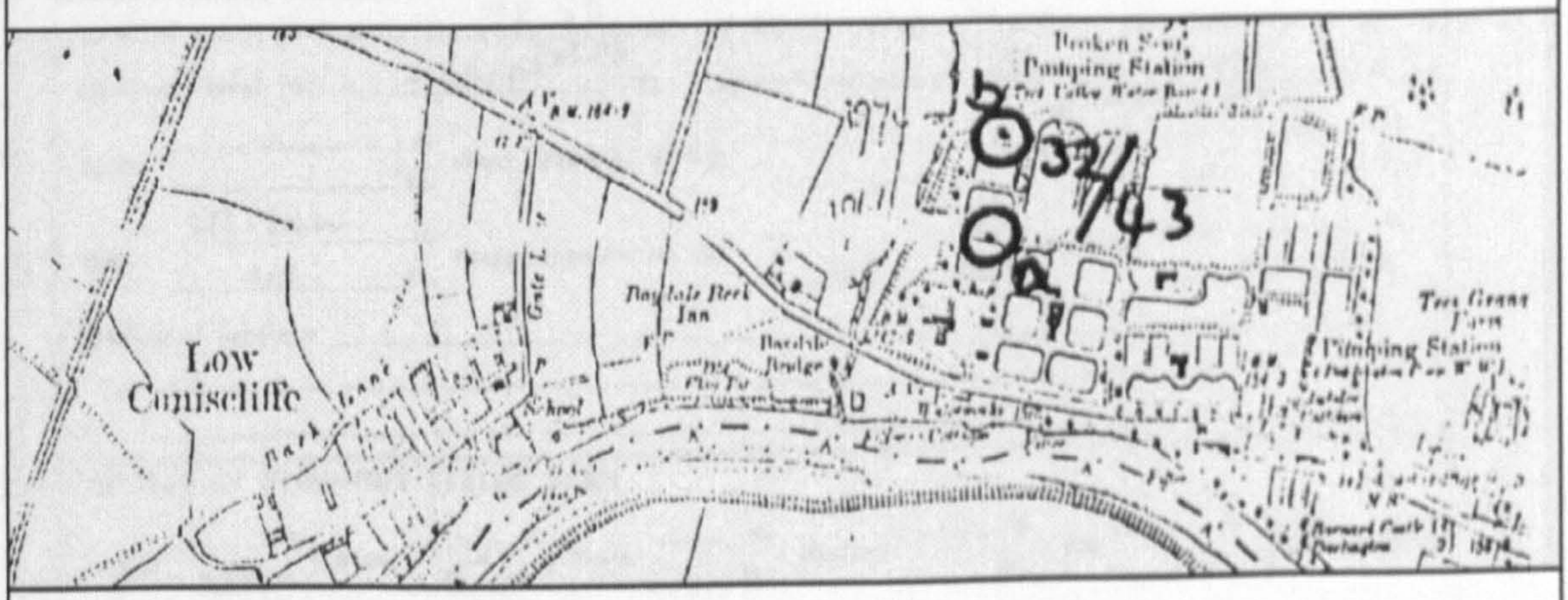
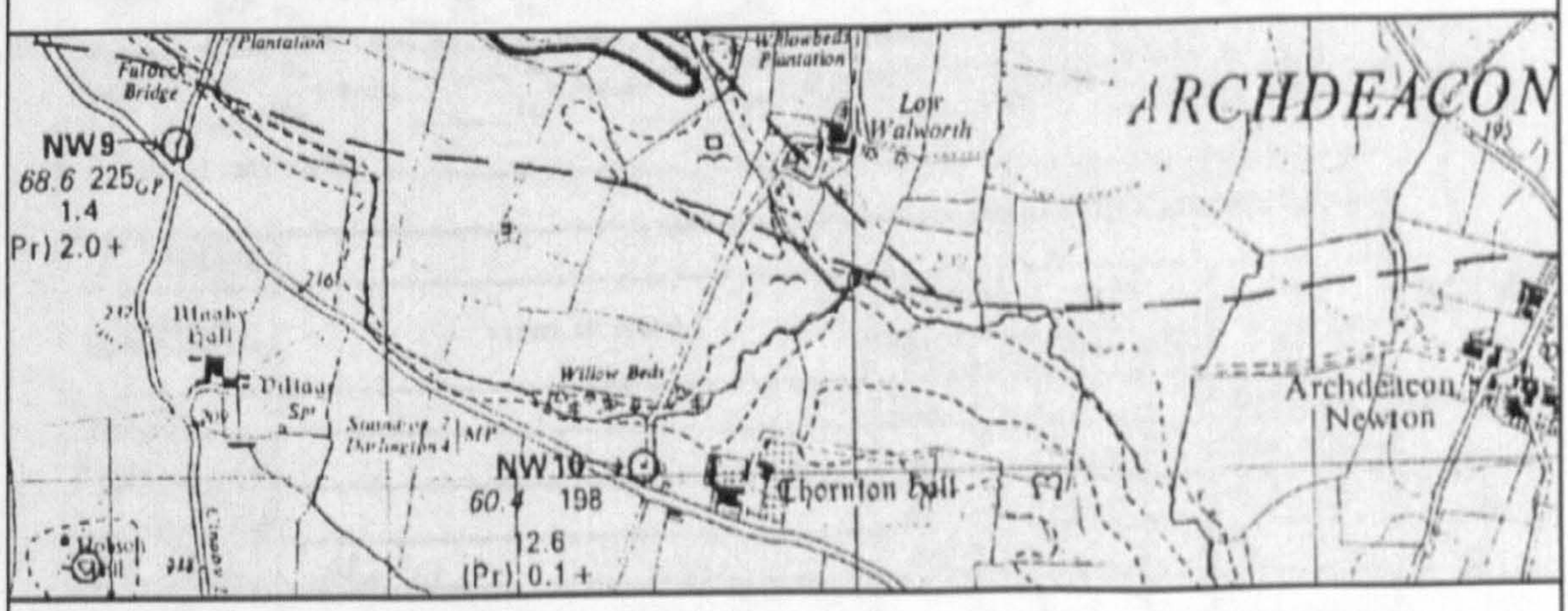



Borehole No. 33/184




Borehole Nos. 32/43 a & b




Borehole Nos. NW 9 & 10

## APPENDIX 1 - Extracts of BGS Typical Location Plans

WATER RESOURCES BOARD
WELL RECORD
SHEET 1

W.R.B. REF. No. NZ 32/23

R.A. LICENCE No.

## 1. WELL IDENTITY

NATIONAL GRID REFERENCE ..... 4 31030 5 22720 .....

Well at R.A. 10 Rickinhall Lane ....

I.G.S. REF. No. .....

RIVER AUTHORITY ..... Northumbrian .....

Town ..... Ryc Close .....

HYDROMETRIC AREA ..... 25 .....

County ..... Durham .....

SUB-CATCHMENT .....

Owner of well Northumbrian RA .....

Well made by Cementation Exploration Ltd Date of sinking 29.12.67 to 17.1.68 ....

Information from Northumbrian R.A. ..... Date received 19.2.68 .....

## 2. WELL DESCRIPTION

Level of ground surface ..... 92.53 m. If well top is not at above* ..... m.

above sea level (O.D.) ~~+308~~ 303.56 ft. ground level how far ~~below~~ ? 2.93 ft.
305.45 ft AOD

Shaft ..... m. deep; Diameter at top ..... m. ; at bottom ..... m.
..... ft. ..... ft. ..... ft.

Bore 91.74m m. deep; Diameter at top ..... m. ; at bottom ..... m.
301 ft. 5" ~~6"~~ 4" ~~4.5"~~ ft.

Details of headings .....

.....

.....

## DETAILS OF PERMANENT LINING TUBES

Length ..... m. ; Diam. ..... m. ; Plain ..... m. ; Slotted ..... m. ; Top ..... m. above* / ~~below~~ surface
133 ft. 5" ~~6"~~ ft. ..... ft. ..... ft. ..... ft.

Length ..... m. ; Diam. ..... m. ; Plain ..... m. ; Slotted ..... m. ; Top ..... m. ~~above*~~ / below surface
29 ft. 6" ft. ..... ft. ..... ft. 133 ft.

Plain slotted casing to hole bottom.

Length ..... m. ; Diam. ..... m. ; Plain ..... m. ; Slotted ..... m. ; Top ..... m. above* / ~~below~~ surface
..... ft. ..... ft. ..... ft. ..... ft. ..... ft.

Details of well screen .....

.....

## 6. STRATA

| GEOLOGICAL CLASSIFICATION | NATURE OF STRATA | THICKNESS FEET | THICKNESS IN. | DEPTH FEET | DEPTH IN. | DEPTH METRES | OD(ft) |
|---|---|---|---|---|---|---|---|
| Drift | | 162 | - | | | 49.38 | +143.6 |
| Middle Mag Lst. | | 67 | - | 229 | - | 69.80 | +74.6 |
| Lower Mag. Lst. | | 47 | - | 276 | - | 84.12 | +27.6 |
| Carboniferous | Shales | 25 | - | 301 | - | 91.74 | +3.6 |
| | | | | | | | |
| | | | | | | | |
| | Carboniferous rocks, shales were initially | | | | | | |
| identified as Permian Marl slate horizon, when | | | | | | | |
| drilling was continued till a dolerite horizon | | | | | | | |
| was encountered | | | | | | | |
| | (T. Johnston's letter of | 25/1/68) | | | | | |

(46452-1) 1

APPENDIX 2 - Extract from BGS Log NZ 32/23

# RECORD OF SHAFT OR BORE FOR MINERALS

6-inch Map Registered No. **33/156**

Name of Shaft or Bore given by Geological Survey:

Name and Number given by owner:

For whom made Messrs. J. Dodds & Brown, Hurworth-on-Tees.

Town or Village Girsby County

Exact site Castle Hill Farm. Attach a tracing from a map, or a sketch-map, if possible.

Purpose for which made obtaining water.

Nat. Grid Reference NZ 3688 0931

| 1"N.S. Map No. | 1"O.S. Map No. | Confidential or not |
|---|---|---|
| 33 | | |

Ground Level at bore relative to O.D. 5" If not ground level give O.D. of beginning of bore 5'L 115

Made by J.T. HYMAS (Well Engineers) Ltd., Burton Leonard. Date of sinking SEPT. '54

Information from J.T. HYMAS (Well Engineers) Ltd., Date received

Examined by

## SPECIMEN NUMBERS AND ADDITIONAL NOTES

| (For Survey use only) Geological Classification | DESCRIPTION OF STRATA | Thickness Ft | Thickness In. | Depth Ft | Depth In. |
|---|---|---|---|---|---|
| | Clay | 48 | 0 | | |
| | Sand. | 3 | 0 | 51 | 0 |
| | Clay and stones. | 42 | 0 | 93 | 0 |
| | Sandy clay. | 15 | 0 | 108 | 0 |
| | Gravel. | 3 | 0 | 111 | 0 |
| | Grey sandstone. | 19 | 0 | 130 | 0 |
| | Red sandstone. | 2 | 0 | 132 | 0 |
| | Grey sandstone. | 99 | 0 | 231 | 0 |
| | No. 1. Borehole registered as 33/139. | | | | |

**APPENDIX 3 - Extract from BGS Log NZ 33/156**

# RECORD OF SHAFT OR BORE FOR MINERALS

County Aberdeen

6" Quarter Sheet 55SE.

1" N.S. Geol. Map 33.

1" O.S. Geol. Map

Whether Confidential

No.

Name and Number of Shaft or Bore given by Geological Survey :

Name and Number given by owner (if different from above) :

Bore at Middlebank - Dyce - Road.

Town or Village Date of sinking 1932

Exact site

A sketch-map or tracing from a large-scale map is desirable.

Purpose for which made

Level at which bore commenced relative to O.D. If not down bore, state if horizontal or up

Made by WM. COULSON LTD. for Messrs Aberdeen County Council

Information from WM. COULSON LTD. Book 9 p. 144 Date received 1941

Specimens Dip of strata

| Geological Classification | Description | Thickness | Depth |
|---|---|---|---|
| | | | |
| | (1) On Boulder Clay, Hall's House. 18" E. of bore at gable end, in opening and below footpath SL c +90 | | |
| | Soil | 3 | 3 |
| | Brown boring clay | 1 3 | 1 6 |
| | " yellow sandstone " clay w. thin sand step | 1 (8) 2 3 | 9 9 |
| | Loamy clay w. thin sand step (& water) | (1) 1 6 | 11 3 |
| | Brown stony clay | 3 (19) 1 3 | 30 6 |
| | Boulder Clay. a little water | 6 (38) 2 3 | 68 9 |
| RH +21 | Red marl & shale. (water) | (1) 1 3 | X 70 0 |
| | | | |
| | (2) On same line 20 above west SL c +70 max 35 | river | |
| | Soil | (1) 1 6 | 1 6 |
| | Sandy clay marl. | (1) 1 6 | 3 0 |
| | Boulder Clay | 1 (9) 3 5 | 12 5 |
| RH +21 | Red stony clay & marl | (1) 1 4 | 13 9 |
| rest level of water 18' 9". +24 | Red marl | 1 (6) 3 | X 20 0 |
| | | ✓ | |
| | (3) On line E end of village below post SL c +70 max 35 | effect | river |
| | Sand | (1) 5 5 | 5 6 |
| | Silty sand & boulders | (3) 5 5 | 8 9 |
| | Brown loamy clay & thin sand steps | (7) 5 9 | 12 5 |
| RH +21 | Gravels. | (1) 1 4 | 13 9 |
| | Red marl | 1 (6) 3 | X 20 0 |
| | | | |
| | | | |

**APPENDIX 4 - Extract from BGS Log NZ 33/55**

NZ21/21

NZ 28751435

(*11938) WL80370/0370 10,000 9/59 A.& E.W.Ltd. Op.686

# RECORD OF SHAFT OR BORE FOR MINERALS 33/73

Name and Number of Shaft or Bore given by Geological Survey :

Name and Number given by owner (if different from above) :

Town or Village Darlington. Date of sinking 28 July 1871.

Exact site At Messrs. Plews & Co's Malting, Darlington.

County DURHAM

6" Quarter Sheet 55

1" N.S. Geol. Map

1" O.S. Geol. Map

Whether Confidential

A sketch-map or tracing from a large-scale map is desirable.

Purpose for which made

Level at which bore commenced relative to O.D. If not down bore, state if horizontal or up.

Made by WM. COULSON LTD. for Messrs. Plews & Co.

Information from WM. COULSON LTD. (Bk 15 p. 481) Date received June 1941

Specimens Dip of strata

| Geological Classification | Description | Thickness ft. | Thickness in. | Depth ft. | Depth in. | |
|---|---|---|---|---|---|---|
| | Surface to scaffold | 0 | 10 | | | |
| | Scaffold :- concrete. | 2 | 3 | 18 | 1 | |
| | Gravel. | 5 | 6 | 19 | 7 | |
| | Sand & water. | 4 | - | 20 | 7 | |
| Drift | Hard stony brown clay with pockets of sand | 3 | 9 | 25 | 4 | |
| | Loamy clay & sand. | 5 | 6 | 27 | 10 | 182'10" |
| | Strong brown clay with a little sand | 2 | - | 30 | 10 | (32'10" |
| | Red clay. | 1 | 11 | 31 | 9 | |
| | Sand & water | 1 | 6 | 32 | 3 | |
| | Soft marl, lat & clay. | 3 | - | 32 | 3 | |
| Magnesian | Strong limestone | 1 | 4 | 32 | 7 | |
| limestone | Soft lat & clay (pipe all in into this) | 1 | 8 | 33 | 3 | |
| | Stone, soft ptgo & water | 1 | 2 | 34 | 5 | |
| | Very soft - with much | 5 | 4 | 35 | 9 | |
| | Hard panch - soft ptgo & | 4 | 9 | 36 | 6 | |
| | Strong crumbly lat. & water | 2 | 9 | 38 | 3 | 233 3" |
| | Hard panch with soft ptgo & water | 1 | - | 40 | 3 | |
| | Soft grey shale. | 3 | 10 | 44 | 1 | 249' 1" |

per Geologist

N.E. Unit

Dec 1976

Now The Camerons Brewery. Hartlepool Yard.

This bore has apparently been done away with.

Visited & sited Δ on Durham 55 S.W/E.

1.3.51. RTV.

OD C150

**APPRENDIX 5 - Extract from BGS Log NZ 33/73**

NZ 32/23

Ack. Chief Mus Swit
I.G.S. Leeds
Rubg
20.2.68

GL.304

Northumbrian River Authority B. H. 10

Approx. N.G.R. NZ 310 258

Cores examined by D. G. Smith.

Core 170' - 212' 6"

Dolomite, cream, saccharoidal (fine sand-grade), soft, very porous, with ubiquitous traces of former sand-grade oolith, some small calcitic patches, and a few medium-sized carbonate-lined cavities. ? Lamellibranch moulds and stromatolite flakes at 180' 8", scattered small pisoliths below this. Calcitic and partly autobrecciated below 181' 10".

Core 184' - 211' 6". About 6' 6" core recovered

Dolomite, buff-cream, saccharoidal (sand-grade), highly porous and with many medium to large irregular cavities, calcitic, with extensive traces of former sand-grade ooliths. Core-fragmented, about 1½' recovered.

Limestone, dolomitic, buff-brown, saccharoidal (sand-grade), highly porous, fairly hard. No trace of probable former oolith. Partly fragmented, about 9" recovered.

Dolomite, cream, oolitic (mainly re-crystallized into silt to fine sand-grade dolomite and rhombs) very porous with many irregular dolomite-lined cavities. Ooliths mostly of sand-grade; no multiple ooliths or pisoliths seen. Oolitic structure almost obliterated below top foot. About 4½ feet recovered

Core 218' 6" - 223', About 2' recovered

Dolomite, as above, partly clearly oolitic, and partly almost completely recrystallized. Scattered small poorly-preserved lamellibranchs.

Core 227' - 230', 11' (?) recovered

Dolomite, as above, but with thin fairly dense harder bands (with some fine stylolites) at 231' 6", 233' 9" and 23?' and a few poorly-preserved lamellibranchs. Foraminifer at c.231'.

Core 239' - 245', About 3' 6" recovered

Dolomite, as above, with several thin denser beds and several saccharoidal non-oolitic beds. Continuous core from 245'

Dolomite, buff-brown, fine-grained with prominent stylolites and solution

APPENDIX 6 - Extract from BGS Log NZ 32/23

Institute of Geological Sciences

# RECORD OF SHAFT OR BOREHOLE

~~CONFIDENTIAL IN CONFIDENCE~~

6-in or 1:10 000 Map Registration No.

NZ 21 NW/ 11

*Name and Number of Shaft or Borehole:*

DT 21-18

National Grid Reference

NZ 2433 1646

*For whom made* MAU

*Town or Village* Darlington *County* Durham

*Exact site (reference to a fixed point on 1-in or 1:50 000 Map)*

Thornton Hall

| 1-in or 1:50 000 New Series Map No. | Enter 'C' if Confidential |
|---|---|
| | C |

*Purpose for which made* Sand and Gravel Survey

*Ground level at shaft bore relative to O.D.* _____ *m. If not ground level give O.D. of beginning of shaft bore* _____ *m.*

*Made by* Strata Survey 6" Shell and Auger - Pilcon *Date of sinking* 26 Sept 74

*Information from* _____ *Examined by* Alan Smith

DT 21-18

Water level 5.0m

0.0 - 0.4 Soil

Specimen Numbers and Additional Notes

1 0.4 - 1.4 ) Sandy
2 1.4 - 2.4 ) clay with
3 2.4 - 3.2 ) pebbles
4 3.2 - 4.2) Silt
5 4.2 - 5.2) clay with
6 5.2 - 6.2) pebbles
7 6.2 - 7.1)
8 7.1 - 8.1 ) Sandy
9 8.1 - 9.1 ) gravel
10 9.1 - 10.1 Pebbly sand
11 10.1 - 11.1 Gravel
12 11.1 - 12.0 Sandy gravel
13 12.0 - 13.0 )
14 13.0 - 14.0 )
15 14.0 - 15.0 ) Stoney
16 15.0 - 16.0 ) silty
17 16.0 - 17.0 ) clay
18 17.0 - 18.0 )
19 18.0 - 19.0 ) Stoney silty
20 19.0 - 20.0 ) clay. Fewer
21 20.0 - 21.0 ) pebbles to
22 21.0 - 22.0 ) base.
23 22.0 - 23.0 ) Increasing
24 23.0 - 24.0 ) proportion
25 24.0 - 24.4 ) of Mag Lst
) to base.

| Geological Classification | Description of Strata | Thickness *metres* | Depth *metres* |
|---|---|---|---|
| | Soil: dk brown firm loamy | 0.4 | 0.4 |
| | | | |
| | Sandy clay with pebbles: General colour yellow | 2.8 | 3.2 |
| | brown at top to dk brown at base. Firm. | | |
| | Med sand throughout and occ. band -(SA) qtz. | | |
| | 1.4 - 3.2 thin grey clay horizons. | | |
| | Pebbles: soft weathered iron stained c (A) sst | | |
| | fracturing in two when clay broken open with | | |
| | grey-white banded sst., cream and grey sst., | | |
| | c (SR) qtzite, f (SR) coal and soft weathered | | |
| | f (SR) - (SA) Mag Lst. | | |
| | 1.4 - 2.4 traces soft creamy coloured f (SR) Lst. | | |
| | f (SA) mudstone. | | |
| | | | |
| | Silty clay with pebbles: Firm dk blue-grey clay. | 3.9 | 7.1 |
| | | | |

**APPENDIX 7 - Extract from BGS Log NZ 21 NW 11**

SANDEMAN, KENNARD & PARTNERS
[illegible] 5TH VICTORIA STREET, NZ 21 NW 2
WESTMINSTER
LONDON, S.W.1.

DARLINGTON [illegible]
BOREHOLE LOG

LOCATION ULNABY HALL — BOREHOLE No. B.H.5.
BOREHOLE DIA ..... — GROUND LEVEL. 204.41 O.D.
DATE 26.10.61 TO .....

| DATE | DESCRIPTION | THICK-NESS | | LOG | WATER TEST | REMARKS | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | CASING DEPTH | WATER LEVEL | TIME |
| | TOP SOIL | | | | | | | |
| | SOFT LOAM | | | | | | | |
| 26.10.61 | 7' SOFT GREY SILTY CLAY | | | | NIL | 4'-12" | WATER AT 8' | |
| | 13' | | | | | | | |
| | 16' BOULDER CLAY | | | | | | 41' | 08.00 |
| 27.10.61 | 20 MED. SIZE CLAY BOUND STONES | | | | ARTESIAN FLOW 1'28' | 4'-28' | | |
| | 24 SAND & GRAVEL, LT. BROWN | 25' | | | | | ARTESIAN | |
| 30.10.61 | 26 SAND & GRAVEL WITH TRACES LST. | | | | | | ARTESIAN | |
| | 35' | | | | | | | |
| 31.10.61 | 42' LIMESTONE | | | | NIL TEST | 6'-42 | ARTESIAN FLOW BUT LESS THAN | |
| | 44'6" HARD LIMESTONE | | | | | | ARTESIAN FLOW [illegible] AT 44' TO 46' | |
| 20.11.61 | 54'6" | | | | NIL TEST | 1'-48' | | |
| | 64'4" | | | | | | ARTESIAN FLOW | |
| 2.11.61 | | | | | NIL TEST | 1'-42' | | |
| | 75' LET & BROKEN LIMESTONE & VERY HARD CLAY | | | | | | | |
| | 91' HARDSTONE SANDSTONE purple | | | | | | | |
| | 105' complete | | | | | | | |

STANDING WATER LEVELS
APRIL 1962

TOP PIEZOMETER - AT GROUND LEVEL
MIDDLE —•—•— } - BETWEEN -3'-6' ABOVE O.D.
BOTTOM —•—•— }

All L.H. Lot.

**APPENDIX 8 - Extract from BGS Log NZ 21 NW 2**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Boring Method : | | | | | | Source : Lewis & Carman | | No. 2814-6001 | | |
| Boring Diameter : | | | | | | Project : Safeway Supermarket Victoria Road | | Sheet of | | |
| Casing Diameter : | | | | | | | | E 428696.60<br>N 514011.50 | | |
| Equipment : | | | | | | Date : Aug 1993. | | GL 43.40 m OD | | |
| Samples & In-situ Tests | | Casing Depth [m] | Water Depth [m] | | | DESCRIPTION OF STRATA | | Depth [m] | Legend | RL [m] | N |
| Depth [m] | Type | | | | | | | | | | |
| | | | | | | MADE GROUND: concrete. | 0.20 | | | | |
| | | | | | | MADE SOIL & pea gravel | 0.50 | | | | |
| | | | | | | MADE Soft brown soily CLAY | 0.90 | | | | |
| 1.00 | P | | | | | Firm brown sandy CLAY | 2.10 | | CA | | 17 |
| 3.00<br>4.80 | P<br>P | | 4.50 ▼<br>5.00 ▽ | | | Loose to medium dense sandy GRAVEL | 5.80 | | GA | | 6<br>27 |
| | | | | | | Brown gravelly CLAY | 6.10 | | CG | | |
| | | | | | | Medium dense GRAVEL. | 6.60 | | G | | |
| | | | 9.20. ▽ | | | Firm to stiff dark brown stony BOULDER CLAY | 9.20 | | BC | | |
| 9.50<br>12.00 | P<br>P | | | | | Medium dense to dense SAND | 14.70 | | A | | 28<br>32 |
| | | | | | | Firm to stiff dark brown stony BOULDER CLAY. | 16.50 | | BC | | |
| | | | | | | End of Borehole | | | | | |

Remarks: 1. See Dunelm Drilling Co Report
2. Labelled Borehole No. 5

**APPENDIX 9 - Standard Borehole Log Showing Typical Taking Off Information**

| | | |
|---|---|---|
| Boring Method : LCP | Source : | Project ID : **29140205** Sheet 1 of 1 |
| Bore Diameter (mm) : | | |
| Casing Diameter (mm) : | Project : **Town Centre Combined** | GL m AOD 36.50 |
| Date Start : 01/08/1958 End : 01/08/1958 | | Coordinates E 429085.00 N 514232.00 |

| Water Strike | Description | Legend Depth (m) | Legend Level (OD) |
|---|---|---|---|
| | MADE GROUND: Soil. | 0.30 | 36.20 |
| | Yellow and brown CLAY. | 1.52 | 34.98 |
| 1.00 | | | |
| | Yellow and dark grey SAND with traces of peat and decayed timber. | 2.61 | 33.99 |
| 2.00 | | | |
| | GRAVEL. | 3.15 | 33.35 |
| 3.00 | | | |
| | Leafy CLAY with thin laminations of sand. | 5.03 | 31.47 |
| 4.00 | | | |
| 5.00 | | | |
| | Leafy CLAY with sand partings - very soft. | 6.10 | 30.40 |
| 6.00 | | | |
| | Sandy? SILT. | 7.24 | 29.26 |
| 7.00 | | | |
| | Red CLAY. | 7.47 | 29.03 |
| | *End of Borehole at 7.47 m* | | |

Remarks :
1 See Wm Coulson Report August 1958 [BH 4]

## APPENDIX 10 - Borehole Log 2914·0502

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| DIRECT | 28137401 | 428757.00 | 513992.50 | 39.540 | 12.500 |
| RIVER | 28137901 | 428757.00 | 513992.50 | 39.540 | 12.500 |
| RR4NOV73 | 28145101 | 428566.80 | 514194.00 | 50.330 | 4.270 |
| RR4NOV73 | 28145201 | 428589.50 | 514225.50 | 49.840 | 6.550 |
| RR5DEC72 | 28145301 | 428551.00 | 514309.20 | 51.880 | 5.930 |
| RR5DEC72 | 28145302 | 428543.80 | 514390.00 | 52.810 | 3.660 |
| RR5DEC72 | 28145401 | 428544.40 | 514443.40 | 53.110 | 3.530 |
| RR5DEC72 | 28145402 | 428546.80 | 514498.00 | 53.370 | 3.360 |
| RR5DEC72 | 28145501 | 428563.20 | 514549.00 | 53.360 | 5.800 |
| RR5DEC72 | 28145502 | 428598.50 | 514597.50 | 52.910 | 5.540 |
| DIRECT | 28145503 | 428540.50 | 514509.50 | 53.370 | 3.000 |
| DIRECT | 28145504 | 428548.00 | 514501.80 | 53.370 | 3.500 |
| DTEAUG77 | 28145601 | 428566.00 | 514653.00 | 53.780 | 25.000 |
| DTEAUG77 | 28145602 | 428588.50 | 514629.00 | 53.600 | 25.000 |
| DTEAUG77 | 28145603 | 428556.00 | 514628.00 | 53.970 | 30.000 |
| WRSDEC92 | 28145701 | 428533.00 | 514787.00 | 51.230 | 5.600 |
| SSVAUG93 | 28146001 | 428696.50 | 514011.50 | 43.400 | 16.500 |
| RR4NOV73 | 28146101 | 428614.50 | 514157.50 | 48.700 | 4.420 |
| RR4NOV73 | 28146102 | 428645.50 | 514199.50 | 49.100 | 5.480 |
| SSVAUG93 | 28146103 | 428653.50 | 514160.00 | 48.410 | 5.000 |
| SSVAUG93 | 28146104 | 428619.50 | 514100.80 | 48.240 | 5.000 |
| SSVJUL94 | 28146105 | 428666.00 | 514159.50 | 48.540 | 19.000 |
| SSVJUL94 | 28146106 | 428684.50 | 514157.50 | 48.270 | 16.000 |
| CRUOCT84 | 28146201 | 428633.50 | 514237.00 | 0.000 | 10.000 |
| CRUOCT84 | 28146202 | 428624.00 | 514233.50 | 0.000 | 2.500 |
| CRUOCT84 | 28146203 | 428613.50 | 514239.50 | 0.000 | 1.500 |
| CRUOCT84 | 28146204 | 428613.00 | 514249.00 | 0.000 | 10.000 |
| CRUOCT84 | 28146205 | 428623.00 | 514258.50 | 0.000 | 1.500 |
| CRUOCT84 | 28146206 | 428635.50 | 514248.50 | 0.000 | 1.000 |
| CRUOCT84 | 28146207 | 428635.50 | 514248.50 | 0.000 | 1.500 |
| CRUOCT84 | 28146208 | 428669.50 | 514245.50 | 0.000 | 2.000 |
| CRUOCT84 | 28146209 | 428667.00 | 514234.00 | 0.000 | 10.000 |
| CRUOCT84 | 28146210 | 428652.00 | 514235.00 | 0.000 | 3.500 |
| DIRECT | 28146211 | 428691.30 | 514282.00 | 48.920 | 6.000 |
| RR5MAR84 | 28146501 | 428622.50 | 514580.50 | 52.220 | 7.000 |
| RR5MAR84 | 28146502 | 428644.00 | 514581.50 | 51.910 | 7.000 |
| RR5DEC72 | 28146601 | 428697.50 | 514670.50 | 51.110 | 5.180 |
| RR5MAR84 | 28146602 | 428685.50 | 514623.30 | 51.760 | 7.000 |
| RR5MAR84 | 28146603 | 428675.50 | 514624.00 | 51.830 | 7.000 |
| RR5MAR84 | 28146604 | 428633.90 | 514610.00 | 52.390 | 6.000 |
| WRSDEC92 | 28146701 | 428651.00 | 514713.50 | 51.500 | 6.000 |
| SSVAUG93 | 28147001 | 428714.50 | 514093.00 | 44.200 | 16.500 |
| SSVAUG93 | 28147002 | 428796.50 | 514067.00 | 38.800 | 20.000 |
| SSVAUG93 | 28147003 | 428783.50 | 514025.40 | 39.210 | 12.000 |
| SSVAUG93 | 28147004 | 428747.00 | 514030.50 | 40.440 | 12.000 |

**APPENDIX 11 - Borehole Data : Town Centre (Sheet 1 of 8)**

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| RR4NOV73 | 28147101 | 428704.00 | 514197.00 | 45.320 | 3.650 |
| RR4NOV73 | 28147102 | 428787.30 | 514176.40 | 41.860 | 4.720 |
| SSVAUG93 | 28147103 | 428770.50 | 514154.50 | 41.330 | 5.000 |
| SSVAUG93 | 28147104 | 428710.30 | 514115.50 | 48.170 | 5.000 |
| MDPJUN85 | 28147105 | 428702.00 | 514141.00 | 0.000 | 10.000 |
| MDPJUN85 | 28147106 | 428774.50 | 514140.50 | 0.000 | 10.000 |
| FSVOCT81 | 28147107 | 428726.50 | 514158.50 | 45.200 | 7.000 |
| FSVOCT81 | 28147108 | 428746.00 | 514162.50 | 43.450 | 6.000 |
| FSVOCT81 | 28147109 | 428743.50 | 514149.50 | 43.450 | 7.000 |
| RHAMAR85 | 28147201 | 428747.00 | 514252.00 | 47.720 | 7.500 |
| RHAMAR85 | 28147202 | 428746.50 | 514238.50 | 48.100 | 2.500 |
| SKSAUG84 | 28147301 | 428744.30 | 514363.70 | 48.850 | 6.250 |
| BGSSLS | 28147302 | 428756.00 | 514339.00 | 48.770 | 75.920 |
| SKSAUG84 | 28147401 | 428730.50 | 514415.40 | 49.600 | 9.100 |
| SKSAUG84 | 28147402 | 428736.50 | 514477.00 | 50.100 | 6.000 |
| SKSAUG84 | 28147501 | 428739.50 | 514519.50 | 50.350 | 5.850 |
| SKSAUG84 | 28147502 | 428746.50 | 514563.00 | 50.700 | 7.050 |
| SKSAUG84 | 28147503 | 428778.50 | 514501.80 | 50.750 | 7.000 |
| WRSDEC92 | 28147601 | 428768.50 | 514666.30 | 50.870 | 6.000 |
| RR3DEC69 | 28147701 | 428719.80 | 514709.30 | 51.350 | 7.620 |
| RR3DEC69 | 28147702 | 428771.00 | 514742.00 | 0.000 | 1.520 |
| SSVAUG93 | 28148001 | 428822.00 | 514091.50 | 37.650 | 5.000 |
| RR4NOV73 | 28148101 | 428831.00 | 514172.30 | 39.500 | 5.490 |
| DIRECT | 28148102 | 428832.50 | 514149.50 | 38.090 | 5.000 |
| MDPJUN85 | 28148103 | 428815.50 | 514119.50 | 38.800 | 10.000 |
| TCDJUN71 | 28148201 | 428837.50 | 514236.50 | 41.360 | 2.440 |
| TCDJUN71 | 28148202 | 428832.10 | 514241.00 | 41.630 | 12.190 |
| TCDJUN71 | 28148203 | 428838.50 | 514244.00 | 41.810 | 2.750 |
| TCDJUN71 | 28148204 | 428843.50 | 514239.00 | 41.430 | 12.190 |
| TCDJUN71 | 28148205 | 428856.50 | 514237.00 | 40.990 | 10.060 |
| TCDJUN71 | 28148206 | 428863.00 | 514280.50 | 43.040 | 15.000 |
| VRDNOV81 | 28148207 | 428855.00 | 514209.50 | 39.800 | 2.600 |
| VRDNOV81 | 28148208 | 428850.00 | 514205.50 | 39.740 | 3.500 |
| TCDJUN71 | 28148301 | 428853.00 | 514316.40 | 44.820 | 15.000 |
| TCDJUN71 | 28148302 | 428844.00 | 514359.00 | 45.910 | 9.150 |
| TCDJUN71 | 28148303 | 428841.00 | 514369.50 | 46.730 | 9.150 |
| TCDJUN71 | 28148304 | 428841.50 | 514384.40 | 47.770 | 10.670 |
| TCDJUN71 | 28148305 | 428850.50 | 514376.50 | 46.760 | 9.150 |
| TCDJUN71 | 28148306 | 428891.00 | 514359.00 | 45.550 | 15.000 |
| DIRECT | 28148307 | 428880.50 | 514367.00 | 45.810 | 6.000 |
| DIRECT | 28148308 | 428877.50 | 514348.00 | 45.120 | 6.000 |
| DIRECT | 28148309 | 428882.50 | 514326.00 | 44.430 | 6.000 |
| DIRECT | 28148310 | 428858.50 | 514329.50 | 44.640 | 6.000 |
| DIRECT | 28148311 | 428856.00 | 514317.50 | 44.900 | 6.000 |
| HRSJUN93 | 28148401 | 428861.50 | 514457.00 | 48.220 | 6.000 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| TCDMAY71 | 28148402 | 428877.80 | 514414.20 | 46.390 | 15.240 |
| TCSOCT82 | 28148404 | 428897.50 | 514408.50 | 45.550 | 8.250 |
| HRSJUN93 | 28148501 | 428871.50 | 514505.60 | 47.880 | 6.000 |
| HRSJUN93 | 28148502 | 428885.00 | 514583.50 | 47.610 | 6.000 |
| TRSAUG91 | 28148503 | 428899.10 | 514510.60 | 46.030 | 6.500 |
| BSRAUG95 | 28148601 | 428879.50 | 514624.30 | 47.690 | 2.800 |
| ODCNOV76 | 28148701 | 428871.60 | 514779.60 | 48.240 | 10.000 |
| ODCNOV76 | 28148702 | 428884.50 | 514772.50 | 48.090 | 7.000 |
| RR3DEC69 | 28148703 | 428810.00 | 514789.50 | 50.530 | 1.520 |
| RR3DEC69 | 28148801 | 428855.00 | 514818.50 | 49.070 | 6.100 |
| RR3DEC69 | 28148802 | 428896.00 | 514840.50 | 47.010 | 1.520 |
| RR4NOV73 | 28149001 | 428997.60 | 514056.00 | 37.180 | 6.420 |
| RR4NOV73 | 28149101 | 428962.00 | 514143.50 | 38.070 | 4.130 |
| TCSOCT82 | 28149102 | 428975.00 | 514184.00 | 37.920 | 8.350 |
| BASMAR90 | 28149103 | 428947.00 | 514176.00 | 38.330 | 7.000 |
| BASMAR90 | 28149104 | 428964.60 | 514171.00 | 39.120 | 7.000 |
| TCDJUN71 | 28149201 | 428902.50 | 514284.50 | 42.090 | 15.000 |
| TCDMAY71 | 28149202 | 428936.00 | 514250.00 | 38.160 | 19.810 |
| TCDMAY71 | 28149203 | 428953.20 | 514266.00 | 38.070 | 19.960 |
| TCSOCT82 | 28149204 | 428980.00 | 514240.50 | 38.170 | 8.150 |
| PIFJAN11 | 28149205 | 428963.00 | 514224.50 | 37.810 | 51.820 |
| TCDJAN71 | 28149301 | 428909.00 | 514383.50 | 45.540 | 15.240 |
| TCDJAN71 | 28149302 | 428955.50 | 514374.00 | 41.970 | 15.700 |
| CIVNOV60 | 28149303 | 428985.50 | 514396.50 | 41.830 | 18.290 |
| CIVNOV60 | 28149304 | 428991.00 | 514391.50 | 41.680 | 9.150 |
| CIVNOV60 | 28149305 | 428973.00 | 514362.50 | 41.000 | 9.150 |
| TCDJAN71 | 28149306 | 428981.20 | 514346.80 | 40.480 | 15.390 |
| CIVNOV60 | 28149307 | 428979.00 | 514325.50 | 40.380 | 9.150 |
| TCDMAY71 | 28149308 | 428962.50 | 514315.00 | 40.660 | 19.810 |
| CIVNOV60 | 28149309 | 428945.50 | 514339.50 | 41.980 | 9.150 |
| TCDJAN71 | 28149310 | 428913.00 | 514349.50 | 44.500 | 15.240 |
| TCDMAY71 | 28149401 | 428905.50 | 514428.30 | 44.810 | 13.870 |
| TCDMAY71 | 28149402 | 428915.50 | 514454.00 | 44.440 | 15.240 |
| TCDMAY71 | 28149403 | 428904.00 | 514484.00 | 45.110 | 13.720 |
| TRSAUG91 | 28149404 | 428967.30 | 514483.50 | 42.100 | 6.300 |
| TCDMAY71 | 28149405 | 428972.80 | 514471.50 | 42.060 | 13.720 |
| TCDMAY71 | 28149406 | 428955.00 | 514449.00 | 43.560 | 13.720 |
| TCDMAY71 | 28149407 | 428949.30 | 514417.00 | 43.460 | 14.330 |
| TRSAUG91 | 28149501 | 428931.50 | 514501.00 | 44.100 | 6.000 |
| CORJAN87 | 28149502 | 428915.00 | 514545.50 | 46.950 | 20.750 |
| CORJAN87 | 28149503 | 428962.00 | 514540.50 | 44.450 | 40.250 |
| CORAPR89 | 28149504 | 428973.50 | 514509.00 | 41.830 | 24.000 |
| CORAPR89 | 28149505 | 428948.60 | 514564.00 | 45.200 | 12.000 |
| CORAPR89 | 28149506 | 428930.50 | 514516.00 | 45.100 | 10.000 |
| CORJAN87 | 28149507 | 428920.00 | 514534.00 | 46.590 | 3.200 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| CORJAN87 | 28149508 | 428957.00 | 514544.00 | 44.810 | 2.900 |
| CORJAN87 | 28149601 | 428953.50 | 514608.60 | 45.100 | 20.000 |
| CORJAN87 | 28149602 | 428970.00 | 514667.00 | 44.800 | 20.000 |
| CORJAN87 | 28149603 | 428986.50 | 514614.90 | 43.800 | 20.000 |
| CORJAN87 | 28149604 | 428988.50 | 514675.50 | 44.670 | 2.600 |
| CORJAN87 | 28149605 | 428957.50 | 514614.50 | 44.980 | 3.000 |
| CORJAN87 | 28149606 | 428982.00 | 514614.00 | 43.940 | 2.100 |
| CSRNOV88 | 28149701 | 428969.50 | 514727.00 | 44.240 | 6.000 |
| RR3DEC69 | 28149801 | 428997.00 | 514821.50 | 45.230 | 7.620 |
| NGHNOV72 | 28149802 | 428980.50 | 514874.90 | 46.670 | 6.320 |
| NGHNOV72 | 28149803 | 428981.00 | 514894.00 | 47.480 | 26.820 |
| NGHNOV72 | 28149804 | 428983.50 | 514895.50 | 47.350 | 12.190 |
| NGHNOV72 | 28149901 | 428976.50 | 514916.20 | 47.100 | 12.190 |
| NGHNOV72 | 28149902 | 428991.50 | 514913.50 | 47.190 | 11.890 |
| NGHNOV72 | 28149903 | 428986.80 | 514912.00 | 47.100 | 20.120 |
| TCSOCT82 | 29140101 | 429033.50 | 514137.50 | 38.750 | 8.800 |
| BSSAPR86 | 29140102 | 429090.00 | 514163.00 | 37.040 | 7.300 |
| RR1NOV60 | 29140103 | 429068.00 | 514169.00 | 36.610 | 18.290 |
| RR1NOV60 | 29140104 | 429089.50 | 514166.00 | 36.910 | 18.290 |
| RR1NOV60 | 29140201 | 429093.00 | 514204.50 | 36.550 | 18.290 |
| NBSAUG58 | 29140202 | 429019.50 | 514300.00 | 37.090 | 6.100 |
| NBSAUG58 | 29140203 | 429092.00 | 514292.50 | 37.370 | 6.400 |
| NBSAUG58 | 29140204 | 429035.00 | 514278.00 | 36.860 | 6.100 |
| NBSAUG58 | 29140205 | 429085.00 | 514232.00 | 0.000 | 7.470 |
| NBSAUG58 | 29140206 | 429012.00 | 514239.00 | 36.810 | 9.140 |
| NBSAUG58 | 29140207 | 429002.00 | 514272.00 | 36.820 | 11.280 |
| FFSOCT37 | 29140208 | 429020.00 | 514295.00 | 36.850 | 3.040 |
| FFSOCT37 | 29140209 | 429011.00 | 514247.00 | 36.840 | 3.050 |
| FFSOCT37 | 29140210 | 429088.50 | 514267.00 | 36.990 | 3.340 |
| CIVMAR66 | 29140301 | 429016.50 | 514312.50 | 36.880 | 9.140 |
| CIVMAR66 | 29140302 | 429031.50 | 514374.30 | 40.230 | 9.140 |
| CIVMAR66 | 29140303 | 429041.50 | 514350.50 | 39.010 | 30.500 |
| CIVMAR66 | 29140304 | 429067.50 | 514335.00 | 38.100 | 15.240 |
| CIVMAR66 | 29140305 | 429081.20 | 514301.40 | 37.800 | 15.240 |
| FFSOCT37 | 29140306 | 429086.00 | 514359.00 | 38.330 | 3.670 |
| FFSOCT37 | 29140307 | 429025.50 | 514354.00 | 39.420 | 3.660 |
| TRSAUG91 | 29140401 | 429002.30 | 514487.00 | 40.400 | 6.000 |
| TRSAUG91 | 29140402 | 429042.00 | 514491.20 | 38.690 | 6.500 |
| TRSAUG91 | 29140403 | 429066.50 | 514493.00 | 38.340 | 6.200 |
| CIVMAR66 | 29140404 | 429010.50 | 514400.80 | 41.450 | 12.190 |
| SCHJAN76 | 29140405 | 429015.30 | 514459.00 | 42.560 | 9.000 |
| SCHJAN76 | 29140406 | 429040.20 | 514459.50 | 41.370 | 9.000 |
| CORJAN87 | 29140501 | 429016.50 | 514514.50 | 41.050 | 30.000 |
| CORJAN87 | 29140502 | 429070.50 | 514579.00 | 38.350 | 20.000 |
| CSSAUG88 | 29140503 | 429068.50 | 514529.00 | 38.540 | 5.100 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| CORAPR89 | 29140504 | 429026.80 | 514544.50 | 40.700 | 24.500 |
| CORAPR89 | 29140505 | 429003.80 | 514571.80 | 40.470 | 24.000 |
| CORJAN87 | 29140601 | 429008.50 | 514631.00 | 41.550 | 38.400 |
| CSRNOV88 | 29140602 | 429029.30 | 514697.50 | 41.540 | 6.100 |
| CSSAUG88 | 29140603 | 429034.10 | 514668.70 | 40.900 | 3.100 |
| CSRNOV88 | 29140604 | 429069.40 | 514677.50 | 39.580 | 8.900 |
| DIRECT | 29140605 | 429077.00 | 514605.00 | 39.280 | 6.000 |
| CSSAUG88 | 29140606 | 429052.50 | 514602.50 | 40.050 | 6.050 |
| CORJAN87 | 29140607 | 429019.50 | 514635.00 | 41.330 | 2.900 |
| CORJAN87 | 29140608 | 429009.00 | 514638.00 | 41.460 | 3.200 |
| DIRECT | 29140701 | 429050.80 | 514734.50 | 40.490 | 0.000 |
| DIRECT | 29140702 | 429058.50 | 514704.50 | 40.060 | 0.000 |
| MASNOV67 | 29140703 | 429066.70 | 514784.20 | 42.990 | 12.190 |
| MASNOV67 | 29140704 | 429081.80 | 514796.50 | 41.490 | 7.010 |
| RR4NOV73 | 29140801 | 429006.30 | 514868.50 | 46.270 | 7.620 |
| CFPAPR94 | 29140802 | 429061.00 | 514848.50 | 45.310 | 10.500 |
| CFPAPR94 | 29140803 | 429090.30 | 514856.50 | 42.750 | 10.500 |
| MASNOV67 | 29140804 | 429062.50 | 514806.00 | 43.830 | 9.140 |
| BSSAPR86 | 29141101 | 429111.50 | 514153.00 | 36.820 | 7.200 |
| RR1NOV60 | 29141102 | 429105.50 | 514187.00 | 37.110 | 20.270 |
| POSFEB80 | 29141103 | 429188.50 | 514186.50 | 37.230 | 10.000 |
| POSFEB80 | 29141104 | 429167.00 | 514181.50 | 37.440 | 10.000 |
| POSFEB80 | 29141105 | 429143.00 | 514178.30 | 37.100 | 10.000 |
| POSFEB80 | 29141106 | 429184.00 | 514169.00 | 37.310 | 10.000 |
| POSFEB80 | 29141107 | 429179.50 | 514152.00 | 37.450 | 8.500 |
| POSFEB80 | 29141108 | 429160.00 | 514155.50 | 37.480 | 10.000 |
| POSFEB80 | 29141109 | 429138.00 | 514160.00 | 37.050 | 10.000 |
| POSFEB80 | 29141110 | 429148.50 | 514198.00 | 37.130 | 10.000 |
| MOSMAR65 | 29141201 | 429143.50 | 514248.50 | 37.200 | 9.000 |
| POSFEB80 | 29141202 | 429171.00 | 514247.00 | 37.310 | 10.000 |
| POSFEB80 | 29141203 | 429184.00 | 514243.50 | 37.550 | 7.000 |
| POSFEB80 | 29141204 | 429199.50 | 514240.00 | 37.550 | 7.000 |
| POSFEB80 | 29141205 | 429178.50 | 514225.00 | 37.480 | 10.000 |
| POSFEB80 | 29141206 | 429163.50 | 514220.00 | 37.040 | 10.000 |
| POSFEB80 | 29141207 | 429195.00 | 514222.00 | 37.450 | 6.300 |
| POSFEB80 | 29141208 | 429152.00 | 514213.00 | 37.480 | 10.000 |
| POSFEB80 | 29141209 | 429193.00 | 514213.50 | 37.440 | 6.300 |
| POSFEB80 | 29141210 | 429193.50 | 514204.50 | 37.260 | 7.100 |
| POSFEB80 | 29141211 | 429174.00 | 514207.50 | 37.370 | 10.000 |
| SCCMAY76 | 29141301 | 429144.00 | 514372.00 | 38.070 | 12.000 |
| CIVMAR66 | 29141302 | 429109.00 | 514342.50 | 38.100 | 15.240 |
| CIVMAR66 | 29141303 | 429114.00 | 514380.00 | 38.710 | 12.190 |
| MOSMAR65 | 29141400 | 0.00 | 0.00 | 39.460 | 6.100 |
| SCCMAY76 | 29141401 | 429155.00 | 514416.20 | 35.520 | 12.000 |
| SCCMAY76 | 29141402 | 429142.50 | 514460.00 | 38.620 | 12.000 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| MOSMAR65 | 29141403 | 429173.00 | 514468.00 | 37.500 | 6.100 |
| MOSMAR65 | 29141501 | 429160.00 | 514598.50 | 37.210 | 6.100 |
| ESBOCT69 | 29141601 | 429141.00 | 514680.20 | 38.760 | 15.850 |
| ESBOCT69 | 29141602 | 429167.00 | 514680.20 | 38.480 | 20.270 |
| DIRECT | 29141603 | 429106.90 | 514698.00 | 39.180 | 0.000 |
| MOSMAR65 | 29141701 | 429154.00 | 514732.00 | 38.800 | 14.780 |
| MOSMAR65 | 29141702 | 429157.40 | 514749.00 | 38.760 | 7.620 |
| MOSMAR65 | 29141703 | 429160.50 | 514765.50 | 38.870 | 19.200 |
| MOSMAR65 | 29141704 | 429179.00 | 514756.00 | 38.070 | 17.070 |
| MOSMAR65 | 29141705 | 429170.50 | 514711.50 | 37.580 | 15.240 |
| DIRECT | 29141706 | 429107.00 | 514753.50 | 39.250 | 0.000 |
| DIRECT | 29141707 | 429145.50 | 514727.60 | 38.700 | 0.000 |
| MOSMAR65 | 29141801 | 429198.50 | 514841.00 | 39.430 | 6.100 |
| LLSJUN84 | 29141802 | 429130.00 | 514842.50 | 39.630 | 6.500 |
| LLSJUN84 | 29141803 | 429133.20 | 514882.60 | 40.530 | 6.000 |
| LLSJUN84 | 29141804 | 429104.30 | 514834.50 | 41.430 | 2.000 |
| LLSJUN84 | 29141805 | 429102.20 | 514895.80 | 42.370 | 6.000 |
| AEBOCT97 | 29141806 | 429160.00 | 514878.50 | 39.850 | 10.000 |
| AEBOCT97 | 29141807 | 429165.50 | 514852.00 | 39.800 | 8.200 |
| VSSMAY94 | 29141902 | 429200.00 | 514938.00 | 39.460 | 6.000 |
| DIRECT | 29142002 | 429291.00 | 514071.00 | 47.200 | 6.500 |
| DIRECT | 29142003 | 429268.80 | 514068.00 | 47.100 | 7.500 |
| RIVER | 29142004 | 429238.00 | 514072.00 | 44.800 | 6.000 |
| DPSMAR59 | 29142301 | 429229.30 | 514382.50 | 37.290 | 12.500 |
| DPSMAR59 | 29142302 | 429229.00 | 514348.50 | 37.200 | 12.190 |
| DPSMAR59 | 29142401 | 429250.00 | 514410.30 | 37.370 | 12.190 |
| DPSMAR59 | 29142402 | 429230.00 | 514415.50 | 37.370 | 6.250 |
| GPHDEC80 | 29142403 | 429276.50 | 514424.00 | 37.420 | 15.000 |
| CPHJUL73 | 29142501 | 429233.00 | 514505.00 | 37.610 | 10.000 |
| CPHJUL73 | 29142502 | 429228.00 | 514507.00 | 37.570 | 4.570 |
| CPHJUL73 | 29142503 | 429241.20 | 514522.60 | 37.850 | 8.850 |
| OSCDEC88 | 29142601 | 429232.00 | 514640.50 | 38.900 | 5.000 |
| OSCDEC88 | 29142602 | 429248.00 | 514667.00 | 39.900 | 5.000 |
| RIVER | 29142603 | 429280.00 | 514695.50 | 40.590 | 6.000 |
| RSPSEP96 | 29142701 | 429249.50 | 514796.00 | 38.400 | 9.000 |
| RSPSEP96 | 29142702 | 429212.50 | 514773.50 | 38.300 | 10.000 |
| RSPSEP96 | 29142703 | 429200.50 | 514752.50 | 38.000 | 10.000 |
| RSPSEP96 | 29142704 | 429222.50 | 514727.50 | 38.100 | 10.000 |
| RSPSEP96 | 29142705 | 429249.00 | 514719.50 | 39.900 | 5.000 |
| RSPSEP96 | 29142706 | 429268.50 | 514729.50 | 40.100 | 5.000 |
| DIRECT | 29143001 | 429319.00 | 514068.00 | 48.300 | 5.000 |
| PGSOCT85 | 29143301 | 429394.00 | 514378.00 | 40.720 | 9.750 |
| PSRJUL87 | 29143302 | 429398.00 | 514387.00 | 40.900 | 10.600 |
| DCTJUN85 | 29143401 | 429304.50 | 514468.50 | 38.230 | 4.800 |
| DCTAUG88 | 29143402 | 429306.00 | 514480.00 | 38.380 | 12.000 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| DCTAUG88 | 29143403 | 429339.50 | 514468.00 | 38.920 | 12.000 |
| RIVER | 29143601 | 429322.00 | 514682.00 | 41.860 | 10.000 |
| DIRECT | 29143602 | 429365.00 | 514665.00 | 41.920 | 6.000 |
| RIVER | 29143603 | 429308.00 | 514653.00 | 41.510 | 6.000 |
| URSFEB95 | 29143701 | 429358.50 | 514797.00 | 44.200 | 10.000 |
| URSFEB95 | 29143702 | 429373.50 | 514796.00 | 44.200 | 12.000 |
| URSFEB95 | 29143703 | 429376.00 | 514784.50 | 44.200 | 11.000 |
| RIVER | 29143704 | 429355.00 | 514704.50 | 43.110 | 6.000 |
| PSRJUL87 | 29144301 | 429417.00 | 514381.50 | 42.080 | 10.550 |
| PMROCT82 | 29144302 | 429412.80 | 514390.00 | 41.760 | 9.400 |
| PSRJUL87 | 29144303 | 429436.00 | 514381.00 | 42.610 | 10.450 |
| PGSOCT85 | 29144304 | 429447.50 | 514378.50 | 42.750 | 10.200 |
| PSRJUL87 | 29144305 | 429456.50 | 514371.00 | 42.880 | 10.550 |
| PSRJUL87 | 29144306 | 429436.00 | 514376.00 | 42.580 | 10.700 |
| PBSAUG88 | 29144307 | 429459.50 | 514339.00 | 47.400 | 6.500 |
| PBSAUG88 | 29144308 | 429472.00 | 514336.50 | 47.490 | 7.000 |
| DIRECT | 29144309 | 429424.00 | 514398.50 | 42.000 | 5.000 |
| PSRJUL87 | 29144401 | 429403.50 | 514401.50 | 40.910 | 10.700 |
| YMCSEP92 | 29144402 | 429479.00 | 514495.50 | 41.950 | 9.500 |
| YMCSEP92 | 29144403 | 429456.50 | 514460.50 | 40.250 | 9.500 |
| CDSAUG88 | 29144404 | 429458.80 | 514456.00 | 40.290 | 9.000 |
| CDSAUG88 | 29144405 | 429466.50 | 514493.40 | 40.250 | 6.500 |
| REMAUG88 | 29144406 | 429475.80 | 514484.00 | 41.000 | 8.500 |
| REMAUG88 | 29144407 | 429493.50 | 514454.90 | 49.380 | 15.000 |
| MSDOCT98 | 29144408 | 429445.00 | 514494.00 | 40.120 | 7.500 |
| MSDOCT98 | 29144409 | 429424.50 | 514496.00 | 40.250 | 8.000 |
| MSDOCT98 | 29144410 | 429413.00 | 514482.50 | 40.500 | 6.000 |
| DIRECT | 29144411 | 429419.00 | 514496.50 | 40.260 | 3.000 |
| DIRECT | 29144412 | 429447.00 | 514486.00 | 40.150 | 3.600 |
| DIRECT | 29144413 | 429444.00 | 514497.00 | 40.110 | 3.400 |
| DIRECT | 29144414 | 429435.00 | 514486.00 | 40.250 | 3.400 |
| YMCSEP92 | 29144501 | 429449.00 | 514566.50 | 41.480 | 10.000 |
| YMCSEP92 | 29144502 | 429481.50 | 514551.00 | 42.000 | 10.000 |
| YMCSEP92 | 29144503 | 429457.50 | 514526.00 | 40.960 | 5.000 |
| YMCSEP92 | 29144504 | 429434.80 | 514521.00 | 39.830 | 5.000 |
| CDSAUG88 | 29144505 | 429468.20 | 514524.00 | 40.900 | 6.500 |
| CDSAUG88 | 29144506 | 429474.00 | 514552.00 | 41.470 | 6.500 |
| CDSAUG88 | 29144507 | 429445.50 | 514572.50 | 41.470 | 6.000 |
| CDSAUG88 | 29144508 | 429449.50 | 514539.50 | 40.980 | 10.000 |
| CDSAUG88 | 29144509 | 429430.50 | 514517.00 | 40.000 | 6.000 |
| REMAUG88 | 29144510 | 429496.40 | 514522.00 | 49.400 | 14.000 |
| DIRECT | 29144601 | 429450.50 | 514631.50 | 42.560 | 5.000 |
| DIRECT | 29144602 | 429483.50 | 514688.50 | 45.170 | 2.930 |
| DIRECT | 29144701 | 429483.70 | 514737.50 | 45.260 | 2.180 |
| DIRECT | 29144702 | 429497.00 | 514736.00 | 45.230 | 2.710 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| DIRECT | 29144703 | 429486.60 | 514753.00 | 45.230 | 2.560 |
| DIRECT | 29144704 | 429482.00 | 514721.00 | 45.170 | 2.790 |
| DIRECT | 29144801 | 429461.00 | 514895.00 | 44.810 | 4.000 |
| DIRECT | 29144804 | 429485.50 | 514889.00 | 44.810 | 2.000 |
| DIRECT | 29144806 | 429493.00 | 514869.50 | 44.810 | 3.000 |
| DIRECT | 29144807 | 429494.00 | 514880.50 | 44.810 | 4.000 |
| DIRECT | 29144808 | 429491.00 | 514854.00 | 44.810 | 4.000 |
| DIRECT | 29144810 | 429451.00 | 514847.00 | 44.810 | 3.000 |
| DIRECT | 29144812 | 429436.50 | 514855.00 | 44.810 | 2.000 |
| DIRECT | 29144813 | 429435.00 | 514870.00 | 44.810 | 3.000 |
| DIRECT | 29144814 | 429424.00 | 514869.00 | 44.810 | 4.000 |
| DIRECT | 29144815 | 429438.50 | 514885.50 | 44.810 | 3.000 |
| DIRECT | 29144816 | 429429.50 | 514842.00 | 44.810 | 3.000 |
| DIRECT | 29144817 | 429421.00 | 514824.00 | 44.810 | 4.000 |
| DIRECT | 29144819 | 429453.00 | 514812.00 | 44.810 | 4.000 |
| DIRECT | 29144820 | 429435.00 | 514879.00 | 44.810 | 5.000 |
| DIRECT | 29144821 | 429433.50 | 514885.00 | 44.810 | 5.000 |
| DIRECT | 29144901 | 429452.50 | 514907.00 | 44.810 | 3.000 |
| DIRECT | 29144902 | 429462.00 | 514901.00 | 44.810 | 4.000 |
| VSSMAY94 | 29152002 | 429205.00 | 515060.00 | 40.380 | 6.000 |

**Total Number of Boreholes = 335 No**

**APPENDIX 11 - Borehole Data : Town Centre (Sheet 8 of 8)**

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| BGSSLS | 28108201 | 428879.00 | 510207.00 | 29.700 | 8.220 |
| BGSSLS | 28109101 | 428921.51 | 510197.00 | 30.020 | 9.740 |
| RSCJAN01 | 28117601 | 428749.00 | 511683.50 | 35.200 | 15.000 |
| RSCJAN01 | 28118601 | 428806.00 | 511692.00 | 32.050 | 12.000 |
| RSCJAN01 | 28119301 | 428942.00 | 511385.00 | 31.380 | 4.800 |
| RSCJAN01 | 28119302 | 428905.00 | 511382.00 | 31.320 | 4.500 |
| RSCJAN01 | 28119601 | 428984.00 | 511642.00 | 30.680 | 15.000 |
| RSCJAN01 | 28123901 | 428389.00 | 512923.00 | 35.200 | 3.050 |
| RSCJAN01 | 28123902 | 428364.50 | 512910.50 | 34.650 | 3.050 |
| RSCJAN01 | 28123903 | 428342.00 | 512905.50 | 34.510 | 2.130 |
| RSCJAN01 | 28123904 | 428313.00 | 512972.30 | 35.650 | 1.830 |
| RSCJAN01 | 28123905 | 428332.00 | 512984.00 | 35.780 | 3.050 |
| RSCJAN01 | 28123906 | 428354.00 | 512953.50 | 35.290 | 2.970 |
| RSCJAN01 | 28124901 | 428423.00 | 512969.50 | 34.790 | 12.050 |
| RSCJAN01 | 28124902 | 428432.50 | 512935.00 | 33.410 | 12.100 |
| RSCJAN01 | 28124903 | 428414.50 | 512974.50 | 34.950 | 3.000 |
| RSCJAN01 | 28124904 | 428427.70 | 512947.00 | 33.620 | 3.500 |
| RSCJAN01 | 28124905 | 428437.00 | 512917.50 | 33.290 | 2.700 |
| RSCJAN01 | 28124906 | 428422.50 | 512904.50 | 32.290 | 1.400 |
| SGCJUL01 | 28127101 | 428715.00 | 512187.00 | 31.820 | 29.000 |
| RSCJAN01 | 28128601 | 428819.00 | 512610.50 | 39.320 | 4.720 |
| RSCJAN01 | 28128602 | 428801.00 | 512605.00 | 38.400 | 4.570 |
| RSCJAN01 | 28129601 | 428919.00 | 512612.50 | 42.060 | 7.620 |
| RSCJAN01 | 28129602 | 428922.50 | 512619.00 | 42.360 | 8.180 |
| RSCJAN01 | 28133001 | 428314.00 | 513007.50 | 36.360 | 3.510 |
| RSCJAN01 | 28133101 | 428367.00 | 513168.50 | 34.960 | 1.300 |
| RSCJAN01 | 28133102 | 428379.50 | 513117.50 | 35.220 | 1.400 |
| DBCSOLID | 28133301 | 428331.00 | 513386.00 | 38.640 | 101.500 |
| SSVAUG93 | 28137901 | 428757.00 | 513992.50 | 39.540 | 12.500 |
| DFCJUN96 | 28138801 | 428890.00 | 513847.50 | 36.670 | 25.200 |
| DFCJUN96 | 28138901 | 428812.00 | 513936.00 | 36.670 | 22.000 |
| DFCJUN96 | 28138902 | 428871.00 | 513952.50 | 36.020 | 25.000 |
| DFCJUN96 | 28139901 | 428912.50 | 513920.00 | 36.530 | 17.200 |
| SSVAUG93 | 28148001 | 428822.00 | 514091.50 | 37.650 | 5.000 |
| RR4NOV73 | 28149001 | 428997.60 | 514056.00 | 37.180 | 6.420 |
| RR4NOV73 | 28149101 | 428962.00 | 514143.50 | 38.070 | 4.130 |
| TCSOCT82 | 28149102 | 428975.00 | 514184.00 | 37.920 | 8.350 |
| BASMAR90 | 28149103 | 428947.00 | 514176.00 | 38.330 | 7.000 |
| BASMAR90 | 28149104 | 428964.60 | 514171.00 | 39.120 | 7.000 |
| TCDMAY71 | 28149202 | 428936.00 | 514250.00 | 38.160 | 19.810 |
| TCDMAY71 | 28149203 | 428953.20 | 514266.00 | 38.070 | 19.960 |
| TCSOCT82 | 28149204 | 428980.00 | 514240.50 | 38.170 | 8.150 |
| PIFJAN11 | 28149205 | 428963.00 | 514224.50 | 37.810 | 51.820 |
| CIVMAR90 | 28149303 | 428985.50 | 514396.50 | 41.830 | 18.290 |
| CIVMAR90 | 28149304 | 428991.00 | 514391.50 | 41.680 | 9.150 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| CIVMAR90 | 28149305 | 428973.00 | 514362.50 | 41.000 | 9.150 |
| CIVMAR90 | 28149307 | 428979.00 | 514325.50 | 40.380 | 9.150 |
| TCDMAY71 | 28149308 | 428962.50 | 514315.00 | 40.660 | 19.810 |
| TRSAUG91 | 28149404 | 428967.30 | 514483.50 | 42.100 | 6.300 |
| TCDMAY71 | 28149405 | 428972.80 | 514471.50 | 42.060 | 13.720 |
| CORJAN87 | 28149503 | 428962.00 | 514540.50 | 44.450 | 40.250 |
| CORAPR89 | 28149504 | 428973.50 | 514509.00 | 41.830 | 24.000 |
| CORJAN87 | 28149507 | 428920.00 | 514534.00 | 46.590 | 3.200 |
| CORJAN87 | 28149508 | 428957.00 | 514544.00 | 44.810 | 2.900 |
| CORJAN87 | 28149602 | 428970.00 | 514667.00 | 44.800 | 20.000 |
| CORJAN87 | 28149603 | 428986.50 | 514614.90 | 43.800 | 20.000 |
| CORJAN87 | 28149604 | 428988.50 | 514675.50 | 44.670 | 2.600 |
| CORJAN87 | 28149605 | 428957.50 | 514614.50 | 44.980 | 3.000 |
| CORJAN87 | 28149606 | 428982.00 | 514614.00 | 43.940 | 2.100 |
| CSRNOV88 | 28149701 | 428969.50 | 514727.00 | 44.240 | 6.000 |
| RR3DEC69 | 28149801 | 428997.00 | 514821.50 | 45.230 | 7.620 |
| RSCJAN01 | 28159301 | 428999.00 | 515366.00 | 44.660 | 7.000 |
| RSCJAN01 | 29110601 | 429011.00 | 511644.00 | 30.690 | 9.500 |
| TCSOCT82 | 29140101 | 429033.50 | 514137.50 | 38.750 | 8.800 |
| BSSAPR86 | 29140102 | 429090.00 | 514163.00 | 37.040 | 7.300 |
| RR1NOV60 | 29140103 | 429068.00 | 514169.00 | 36.610 | 18.290 |
| RR1NOV60 | 29140104 | 429089.50 | 514166.00 | 36.910 | 18.290 |
| RR1NOV60 | 29140201 | 429093.00 | 514204.50 | 36.550 | 18.290 |
| NBSAUG88 | 29140202 | 429019.50 | 514300.00 | 37.090 | 6.100 |
| NBSAUG88 | 29140203 | 429092.00 | 514292.50 | 37.370 | 6.400 |
| NBSAUG88 | 29140204 | 429035.00 | 514278.00 | 36.860 | 6.100 |
| NBSAUG88 | 29140205 | 429085.00 | 514232.00 | 0.000 | 7.470 |
| NBSAUG88 | 29140206 | 429012.00 | 514239.00 | 36.810 | 9.140 |
| NBSAUG88 | 29140207 | 429002.00 | 514272.00 | 36.820 | 11.280 |
| FFSOCT37 | 29140208 | 429020.00 | 514295.00 | 36.850 | 3.040 |
| FFSOCT37 | 29140209 | 429011.00 | 514247.00 | 36.840 | 3.050 |
| FFSOCT37 | 29140210 | 429088.50 | 514267.00 | 36.990 | 3.340 |
| CIVMAR66 | 29140301 | 429016.50 | 514312.50 | 36.880 | 9.140 |
| CIVMAR66 | 29140302 | 429031.50 | 514374.30 | 40.230 | 9.140 |
| CIVMAR66 | 29140303 | 429041.50 | 514350.50 | 39.010 | 30.500 |
| CIVMAR66 | 29140304 | 429067.50 | 514335.00 | 38.100 | 15.240 |
| CIVMAR66 | 29140305 | 429081.20 | 514301.40 | 37.800 | 15.240 |
| FFSOCT37 | 29140306 | 429086.00 | 514359.00 | 38.330 | 3.670 |
| FFSOCT37 | 29140307 | 429025.50 | 514354.00 | 39.420 | 3.660 |
| TRSAUG91 | 29140401 | 429002.30 | 514487.00 | 40.400 | 6.000 |
| TRSAUG91 | 29140402 | 429042.00 | 514491.20 | 38.690 | 6.500 |
| TRSAUG91 | 29140403 | 429066.50 | 514493.00 | 38.340 | 6.200 |
| CIVMAR66 | 29140404 | 429010.50 | 514400.80 | 41.450 | 12.190 |
| SCHJAN76 | 29140405 | 429015.30 | 514459.00 | 42.560 | 9.000 |
| SCHJAN76 | 29140406 | 429040.20 | 514459.50 | 41.370 | 9.000 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| CORJAN87 | 29140501 | 429016.50 | 514514.50 | 41.050 | 30.000 |
| CORJAN87 | 29140502 | 429070.50 | 514579.00 | 38.350 | 20.000 |
| CSSAUG88 | 29140503 | 429068.50 | 514529.00 | 38.540 | 5.100 |
| CORAPR89 | 29140504 | 429026.80 | 514544.50 | 40.700 | 24.500 |
| CORAPR89 | 29140505 | 429003.80 | 514571.80 | 40.470 | 24.000 |
| CORJAN87 | 29140601 | 429008.50 | 514631.00 | 41.550 | 38.400 |
| CSRNOV88 | 29140602 | 429029.30 | 514697.50 | 41.540 | 6.100 |
| CSSAUG88 | 29140603 | 429034.10 | 514668.70 | 40.900 | 3.100 |
| CSRNOV88 | 29140604 | 429069.40 | 514677.50 | 39.580 | 8.900 |
| CSRNOV88 | 29140605 | 429077.00 | 514605.00 | 39.280 | 6.000 |
| CSSAUG88 | 29140606 | 429052.50 | 514602.50 | 40.050 | 6.050 |
| CORJAN87 | 29140607 | 429019.50 | 514635.00 | 41.330 | 2.900 |
| CORJAN87 | 29140608 | 429009.00 | 514638.00 | 41.460 | 3.200 |
| MASNOV67 | 29140703 | 429066.70 | 514784.20 | 42.990 | 12.190 |
| MASNOV67 | 29140704 | 429081.80 | 514796.50 | 41.490 | 7.010 |
| RR3DEC69 | 29140801 | 429006.30 | 514868.50 | 46.270 | 7.620 |
| CFPAPR94 | 29140802 | 429061.00 | 514848.50 | 45.310 | 10.500 |
| CFPAPR94 | 29140803 | 429090.30 | 514856.50 | 42.750 | 10.500 |
| MASNOV67 | 29140804 | 429062.50 | 514806.00 | 43.830 | 9.140 |
| BSSAPR86 | 29141101 | 429111.50 | 514153.00 | 36.820 | 7.200 |
| RR1NOV60 | 29141102 | 429105.50 | 514187.00 | 37.110 | 20.270 |
| POSFEB80 | 29141103 | 429188.50 | 514186.50 | 37.230 | 10.000 |
| POSFEB80 | 29141104 | 429167.00 | 514181.50 | 37.440 | 10.000 |
| POSFEB80 | 29141105 | 429143.00 | 514178.30 | 37.100 | 10.000 |
| POSFEB80 | 29141106 | 429184.00 | 514169.00 | 37.310 | 10.000 |
| POSFEB80 | 29141107 | 429179.50 | 514152.00 | 37.450 | 8.500 |
| POSFEB80 | 29141108 | 429160.00 | 514155.50 | 37.480 | 10.000 |
| POSFEB80 | 29141109 | 429138.00 | 514160.00 | 37.050 | 10.000 |
| POSFEB80 | 29141110 | 429148.50 | 514198.00 | 37.130 | 10.000 |
| MOSMAR65 | 29141201 | 429143.50 | 514248.50 | 37.200 | 9.000 |
| POSFEB80 | 29141202 | 429171.00 | 514247.00 | 37.310 | 10.000 |
| POSFEB80 | 29141203 | 429184.00 | 514243.50 | 37.550 | 7.000 |
| POSFEB80 | 29141204 | 429199.50 | 514240.00 | 37.550 | 7.000 |
| POSFEB80 | 29141205 | 429178.50 | 514225.00 | 37.480 | 10.000 |
| POSFEB80 | 29141206 | 429163.50 | 514220.00 | 37.040 | 10.000 |
| POSFEB80 | 29141207 | 429195.00 | 514222.00 | 37.450 | 6.300 |
| POSFEB80 | 29141208 | 429152.00 | 514213.00 | 37.480 | 10.000 |
| POSFEB80 | 29141209 | 429193.00 | 514213.50 | 37.440 | 6.300 |
| POSFEB80 | 29141210 | 429193.50 | 514204.50 | 37.260 | 7.100 |
| POSFEB80 | 29141211 | 429174.00 | 514207.50 | 37.370 | 10.000 |
| SCCMAY76 | 29141301 | 429144.00 | 514372.00 | 38.070 | 12.000 |
| CIVMAR66 | 29141302 | 429109.00 | 514342.50 | 38.100 | 15.240 |
| CIVMAR66 | 29141303 | 429114.00 | 514380.00 | 38.710 | 12.190 |
| SCCMAY76 | 29141401 | 429155.00 | 514416.20 | 35.520 | 12.000 |
| SCCMAY76 | 29141402 | 429142.50 | 514460.00 | 38.620 | 12.000 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| MOSMAR65 | 29141403 | 429173.00 | 514468.00 | 37.500 | 6.100 |
| MOSMAR65 | 29141501 | 429160.00 | 514598.50 | 37.210 | 6.100 |
| ESBOCT89 | 29141601 | 429141.00 | 514680.20 | 38.760 | 15.850 |
| ESBOCT89 | 29141602 | 429167.00 | 514680.20 | 38.480 | 20.270 |
| MOSMAR65 | 29141701 | 429154.00 | 514732.00 | 38.800 | 14.780 |
| MOSMAR65 | 29141702 | 429157.40 | 514749.00 | 38.760 | 7.620 |
| MOSMAR65 | 29141703 | 429160.50 | 514765.50 | 38.870 | 19.200 |
| MOSMAR65 | 29141704 | 429179.00 | 514756.00 | 38.070 | 17.070 |
| MOSMAR65 | 29141705 | 429170.50 | 514711.50 | 37.580 | 15.240 |
| MOSMAR65 | 29141801 | 429198.50 | 514841.00 | 39.430 | 6.100 |
| LLSJUN84 | 29141802 | 429130.00 | 514842.50 | 39.630 | 6.500 |
| LLSJUN84 | 29141803 | 429133.20 | 514882.60 | 40.530 | 6.000 |
| LLSJUN84 | 29141804 | 429104.30 | 514834.50 | 41.430 | 2.000 |
| LLSJUN84 | 29141805 | 429102.20 | 514895.80 | 42.370 | 6.000 |
| VSSMAY94 | 29141902 | 429200.00 | 514938.00 | 39.460 | 6.000 |
| VRHMAR99 | 29142004 | 429238.00 | 514072.00 | 44.800 | 6.000 |
| DPSMAR59 | 29142301 | 429229.30 | 514382.50 | 37.290 | 12.500 |
| DPSMAR59 | 29142302 | 429229.00 | 514348.50 | 37.200 | 12.190 |
| DPSMAR59 | 29142401 | 429250.00 | 514410.30 | 37.370 | 12.190 |
| DPSMAR59 | 29142402 | 429230.00 | 514415.50 | 37.370 | 6.250 |
| GPHDEC80 | 29142403 | 429276.50 | 514424.00 | 37.420 | 15.000 |
| CPHJUL73 | 29142501 | 429233.00 | 514505.00 | 37.610 | 10.000 |
| CPHJUL73 | 29142502 | 429228.00 | 514507.00 | 37.570 | 4.570 |
| CPHJUL73 | 29142503 | 429241.20 | 514522.60 | 37.850 | 8.850 |
| OSCDEC88 | 29142601 | 429232.00 | 514640.50 | 38.900 | 5.000 |
| OSCDEC88 | 29142602 | 429248.00 | 514667.00 | 39.900 | 5.000 |
| TRCDEC82 | 29142603 | 429280.00 | 514695.50 | 40.590 | 6.000 |
| RSPSEP96 | 29142701 | 429249.50 | 514796.00 | 38.400 | 9.000 |
| RSPSEP96 | 29142702 | 429212.50 | 514773.50 | 38.300 | 10.000 |
| RSPSEP96 | 29142703 | 429200.50 | 514752.50 | 38.000 | 10.000 |
| RSPSEP96 | 29142704 | 429222.50 | 514727.50 | 38.100 | 10.000 |
| RSPSEP96 | 29142705 | 429249.00 | 514719.50 | 39.900 | 5.000 |
| RSPSEP96 | 29142706 | 429268.50 | 514729.50 | 40.100 | 5.000 |
| DCTJUN85 | 29143401 | 429304.50 | 514468.50 | 38.230 | 4.800 |
| DCTAUG88 | 29143402 | 429306.00 | 514480.00 | 38.380 | 12.000 |
| DCTAUG88 | 29143403 | 429339.50 | 514468.00 | 38.920 | 12.000 |
| TRCDEC82 | 29143601 | 429322.00 | 514682.00 | 41.860 | 10.000 |
| TRCDEC82 | 29143603 | 429308.00 | 514653.00 | 41.510 | 6.000 |
| URSFEB95 | 29143701 | 429358.50 | 514797.00 | 44.200 | 10.000 |
| URSFEB95 | 29143702 | 429373.50 | 514796.00 | 44.200 | 12.000 |
| TRCDEC82 | 29143704 | 429355.00 | 514704.50 | 43.110 | 6.000 |
| RSCJAN01 | 29150301 | 429010.50 | 515387.00 | 44.800 | 6.000 |
| RSCJAN01 | 29150302 | 429016.00 | 515357.00 | 43.810 | 5.500 |
| RSCJAN01 | 29150501 | 429077.60 | 515560.40 | 42.250 | 5.000 |
| RSCJAN01 | 29150502 | 429088.13 | 515558.50 | 41.620 | 1.500 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| RSCJAN01 | 29150503 | 429084.80 | 515553.00 | 41.340 | 3.000 |
| RSCJAN01 | 29150504 | 429067.00 | 515558.30 | 41.660 | 3.000 |
| RSCJAN01 | 29150505 | 429076.50 | 515569.00 | 42.750 | 1.630 |
| RSCJAN01 | 29150506 | 429093.00 | 515564.50 | 41.590 | 1.650 |
| RSCJAN01 | 29150507 | 429071.50 | 515191.50 | 44.420 | 3.000 |
| RSCJAN01 | 29150508 | 429083.80 | 515555.50 | 41.840 | 3.000 |
| RSCJAN01 | 29150509 | 429079.00 | 515587.50 | 43.670 | 3.000 |
| RSCJAN01 | 29150510 | 429067.50 | 515566.00 | 43.310 | 3.000 |
| RSCJAN01 | 29150511 | 429093.30 | 515580.30 | 42.400 | 3.000 |
| RSCJAN01 | 29150512 | 429095.80 | 515571.00 | 41.750 | 0.800 |
| RSCJAN01 | 29150513 | 429088.80 | 515578.00 | 42.090 | 3.000 |
| RSCJAN01 | 29150701 | 429080.00 | 515772.00 | 46.000 | 3.700 |
| RSCJAN01 | 29150702 | 429081.00 | 515762.00 | 49.550 | 10.100 |
| RSCJAN01 | 29150704 | 429078.50 | 515765.00 | 49.400 | 5.000 |
| RSCJAN01 | 29150802 | 429097.00 | 515815.00 | 50.310 | 3.500 |
| RSCJAN01 | 29150805 | 429078.00 | 515801.00 | 50.100 | 8.750 |
| RSCJAN01 | 29151202 | 429135.00 | 515256.00 | 40.620 | 8.100 |
| RSCJAN01 | 29151203 | 429157.00 | 515276.00 | 40.270 | 7.100 |
| RSCJAN01 | 29151204 . | 429168.00 | 515285.00 | 40.380 | 6.500 |
| RSCJAN01 | 29151205 | 429190.00 | 515293.00 | 40.380 | 6.200 |
| RSCJAN01 | 29151301 | 429125.50 | 515302.50 | 40.070 | 6.250 |
| RSCJAN01 | 29151302 | 429116.00 | 515368.00 | 40.040 | 6.100 |
| RSCJAN01 | 29151401 | 429112.50 | 515415.00 | 40.310 | 6.100 |
| RSCJAN01 | 29151402 | 429117.00 | 515471.50 | 40.220 | 6.100 |
| RSCJAN01 | 29151501 | 429107.50 | 515501.00 | 40.360 | 8.230 |
| RSCJAN01 | 29151502 | 429106.00 | 515520.50 | 40.330 | 8.230 |
| RSCJAN01 | 29151503 | 429117.50 | 515544.50 | 40.640 | 8.380 |
| RSCJAN01 | 29151504 | 429112.00 | 515544.50 | 40.610 | 6.100 |
| RSCJAN01 | 29151505 | 429127.50 | 515571.00 | 43.710 | 12.650 |
| RSCJAN01 | 29151506 | 429177.00 | 515595.50 | 47.130 | 10.000 |
| RSCJAN01 | 29151507 | 429186.00 | 515577.00 | 40.900 | 10.000 |
| RSCJAN01 | 29151508 | 429146.48 | 515543.49 | 40.950 | 5.000 |
| RSCJAN01 | 29151511 | 429115.38 | 515549.96 | 40.790 | 1.400 |
| RSCJAN01 | 29151516 | 429117.76 | 515544.88 | 40.620 | 1.100 |
| RSCJAN01 | 29151517 | 429130.18 | 515542.05 | 40.720 | 1.800 |
| RSCJAN01 | 29151519 | 429177.50 | 515535.00 | 40.040 | 1.770 |
| RSCJAN01 | 29151520 | 429141.50 | 515540.00 | 40.620 | 3.000 |
| RSCJAN01 | 29151521 | 429125.50 | 515543.50 | 40.680 | 3.000 |
| RSCJAN01 | 29151522 | 429104.50 | 515547.50 | 41.620 | 1.250 |
| RSCJAN01 | 29151523 | 429117.60 | 515558.00 | 40.830 | 1.600 |
| RSCJAN01 | 29151524 | 429138.50 | 515552.50 | 41.120 | 1.700 |
| RSCJAN01 | 29151526 | 429151.50 | 515540.00 | 40.260 | 3.000 |
| RSCJAN01 | 29151527 | 429114.00 | 515570.40 | 41.870 | 4.500 |
| RSCJAN01 | 29151528 | 429123.00 | 515562.80 | 42.610 | 4.100 |
| RSCJAN01 | 29151601 | 429163.50 | 515528.50 | 46.210 | 5.300 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| RSCJAN01 | 29151602 | 429161.00 | 515530.00 | 46.210 | 2.130 |
| RSCJAN01 | 29151603 | 429170.00 | 515529.00 | 46.240 | 12.190 |
| RSCJAN01 | 29151604 | 429180.00 | 515560.50 | 46.640 | 12.190 |
| RSCJAN01 | 29151605 | 429185.00 | 515518.00 | 46.570 | 10.000 |
| RSCJAN01 | 29151606 | 429194.00 | 515538.50 | 46.800 | 10.000 |
| RSCJAN01 | 29151607 | 429194.00 | 515584.50 | 47.030 | 10.000 |
| RSCJAN01 | 29151701 | 429172.50 | 515587.00 | 49.720 | 5.000 |
| RSCJAN01 | 29151702 | 429162.00 | 515569.50 | 48.540 | 6.000 |
| RSCJAN01 | 29151703 | 429192.50 | 515547.50 | 46.610 | 6.000 |
| RSCJAN01 | 29151704 | 429168.50 | 515726.50 | 47.380 | 6.000 |
| RSCJAN01 | 29151705 | 429144.00 | 515747.50 | 48.150 | 5.000 |
| RSCJAN01 | 29151706 | 429164.00 | 515748.00 | 47.530 | 5.000 |
| RSCJAN01 | 29151707 | 429141.00 | 515780.00 | 49.130 | 3.500 |
| RSCJAN01 | 29151708 | 429116.50 | 515751.50 | 48.880 | 3.500 |
| RSCJAN01 | 29151709 | 429125.00 | 515725.00 | 48.370 | 8.750 |
| RSCJAN01 | 29151710 | 429165.00 | 515723.00 | 47.680 | 9.800 |
| RSCJAN01 | 29151711 | 429186.00 | 515708.50 | 47.680 | 6.000 |
| RSCJAN01 | 29151801 | 429176.50 | 515844.50 | 51.360 | 4.000 |
| RSCJAN01 | 29151802 | 429148.00 | 515834.00 | 51.110 | 3.400 |
| RSCJAN01 | 29151803 | 429121.00 | 515856.00 | 51.730 | 3.500 |
| RSCJAN01 | 29152001 | 429201.00 | 515005.00 | 39.460 | 6.100 |
| RSCJAN01 | 29152002 | 429205.00 | 515060.00 | 40.380 | 6.000 |
| RSCJAN01 | 29152105 | 429298.50 | 515124.50 | 40.140 | 15.000 |
| RSCJAN01 | 29152106 | 429270.00 | 515137.00 | 39.930 | 15.000 |
| RSCJAN01 | 29152107 | 429240.50 | 515151.50 | 39.730 | 5.000 |
| RSCJAN01 | 29152108 | 429242.50 | 515131.50 | 39.670 | 15.000 |
| RSCJAN01 | 29152109 | 429264.00 | 515167.00 | 39.990 | 5.500 |
| RSCJAN01 | 29152110 | 429299.50 | 515167.50 | 40.230 | 5.500 |
| RSCJAN01 | 29152111 | 429291.00 | 515102.00 | 40.020 | 2.300 |
| RSCJAN01 | 29152112 | 429297.00 | 515150.00 | 40.200 | 1.400 |
| RSCJAN01 | 29152201 | 429253.00 | 515293.00 | 40.990 | 6.000 |
| RSCJAN01 | 29152202 | 429290.00 | 515270.00 | 40.400 | 5.300 |
| RSCJAN01 | 29152601 | 429202.00 | 515607.50 | 40.120 | 10.000 |
| RSCJAN01 | 29152602 | 429211.50 | 515631.00 | 40.140 | 10.000 |
| RSCJAN01 | 29152603 | 429219.50 | 515666.50 | 40.590 | 10.000 |
| RSCJAN01 | 29152604 | 429202.00 | 515162.50 | 47.000 | 10.000 |
| RSCJAN01 | 29152605 | 429203.50 | 515637.00 | 43.140 | 2.000 |
| RSCJAN01 | 29152701 | 429267.00 | 515791.00 | 43.630 | 7.000 |
| RSCJAN01 | 29152702 | 429245.00 | 515790.50 | 45.970 | 5.000 |
| RSCJAN01 | 29152703 | 429204.00 | 515747.00 | 45.790 | 10.200 |
| RSCJAN01 | 29152704 | 429203.50 | 515799.50 | 48.450 | 5.000 |
| RSCJAN01 | 29152705 | 429203.00 | 515718.00 | 44.600 | 7.600 |
| RSCJAN01 | 29152706 | 429211.00 | 515716.50 | 42.790 | 7.620 |
| RSCJAN01 | 29152707 | 429257.00 | 515765.00 | 45.220 | 12.190 |
| RSCJAN01 | 29152801 | 429202.00 | 515884.00 | 52.330 | 4.000 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| RSCJAN01 | 29152802 | 429265.00 | 515899.50 | 50.900 | 10.000 |
| RSCJAN01 | 29152803 | 429272.00 | 515242.00 | 46.930 | 4.500 |
| RSCJAN01 | 29152901 | 429225.00 | 515923.00 | 52.800 | 4.500 |
| RSCJAN01 | 29152902 | 429248.00 | 515963.00 | 52.000 | 3.500 |
| RSCJAN01 | 29153103 | 429331.00 | 515114.00 | 40.400 | 2.400 |
| RSCJAN01 | 29153104 | 429313.00 | 515137.00 | 40.300 | 0.900 |
| RSCJAN01 | 29153105 | 429336.50 | 515173.00 | 40.440 | 1.000 |
| RSCJAN01 | 29153701 | 429310.50 | 515378.00 | 52.040 | 8.000 |
| RSCJAN01 | 29153702 | 429347.50 | 515775.50 | 51.840 | 2.750 |
| RSCJAN01 | 29153703 | 429381.50 | 515781.50 | 52.060 | 2.500 |
| RSCJAN01 | 29153704 | 429376.50 | 515725.00 | 52.610 | 3.500 |
| RSCJAN01 | 29153705 | 429359.00 | 515766.50 | 52.060 | 3.300 |
| RSCJAN01 | 29153706 | 429304.50 | 515737.00 | 52.250 | 18.000 |
| RSCJAN01 | 29153801 | 429302.00 | 515877.50 | 47.140 | 5.000 |
| RSCJAN01 | 29153803 | 429378.00 | 515823.00 | 51.980 | 8.250 |
| RSCJAN01 | 29153804 | 429358.50 | 515815.50 | 52.130 | 17.500 |
| RSCJAN01 | 29153805 | 429318.50 | 515855.50 | 42.820 | 6.100 |
| RSCJAN01 | 29153901 | 429352.50 | 515909.00 | 44.630 | 7.000 |
| RSCJAN01 | 29153902 | 429328.50 | 515914.00 | 47.440 | 5.000 |
| RSCJAN01 | 29153903 | 429315.50 | 515974.00 | 49.510 | 5.000 |
| RSCJAN01 | 29153904 | 429361.00 | 515948.00 | 46.590 | 5.000 |
| RSCJAN01 | 29154601 | 429455.50 | 515667.00 | 52.050 | 8.000 |
| RSCJAN01 | 29154701 | 429482.50 | 515707.00 | 51.660 | 4.000 |
| RSCJAN01 | 29154702 | 429406.00 | 515759.00 | 52.370 | 11.000 |
| RSCJAN01 | 29154703 | 429456.50 | 515760.50 | 52.400 | 10.500 |
| RSCJAN01 | 29154801 | 429419.00 | 515874.50 | 51.810 | 8.000 |
| RSCJAN01 | 29154802 | 429409.50 | 515862.50 | 51.840 | 17.500 |
| RSCJAN01 | 29154803 | 429453.50 | 515859.50 | 51.760 | 6.000 |
| RSCJAN01 | 29154804 | 429486.00 | 515809.50 | 51.980 | 10.000 |
| RSCJAN01 | 29154805 | 429458.50 | 515810.00 | 52.030 | 3.750 |
| RSCJAN01 | 29154806 | 429409.00 | 515712.00 | 51.820 | 1.200 |
| RSCJAN01 | 29154901 | 429459.00 | 515709.50 | 51.600 | 8.100 |
| RSCJAN01 | 29154902 | 429463.50 | 515930.00 | 52.040 | 18.000 |
| RSCJAN01 | 29154903 | 429407.00 | 515943.00 | 44.010 | 6.710 |
| RSCJAN01 | 29155705 | 429507.00 | 515759.50 | 51.880 | 3.100 |
| RSCJAN01 | 29155706 | 429504.00 | 515760.00 | 51.880 | 3.000 |
| RSCJAN01 | 29155801 | 429510.00 | 515857.50 | 52.050 | 14.000 |
| RSCJAN01 | 29155802 | 429515.00 | 515895.00 | 52.140 | 18.000 |
| RSCJAN01 | 29155803 | 429572.00 | 515855.00 | 52.620 | 10.000 |
| RSCJAN01 | 29155804 | 429558.00 | 515805.00 | 52.290 | 10.000 |
| RSCJAN01 | 29155901 | 429511.00 | 515907.50 | 52.440 | 8.500 |
| RSCJAN01 | 29155902 | 429513.00 | 515953.00 | 52.290 | 8.200 |
| RSCJAN01 | 29155903 | 429525.00 | 515953.00 | 52.590 | 8.150 |
| RSCJAN01 | 29155904 | 429559.00 | 515901.50 | 52.870 | 8.300 |
| RSCJAN01 | 29155905 | 429515.00 | 515958.00 | 52.350 | 18.000 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| RSCJAN01 | 29155906 | 429565.00 | 515947.00 | 52.940 | 8.000 |
| RSCJAN01 | 29155907 | 429562.00 | 515906.00 | 52.760 | 15.500 |
| RSCJAN01 | 29156801 | 429606.50 | 515850.00 | 52.890 | 8.200 |
| RSCJAN01 | 29156802 | 429610.50 | 515899.50 | 53.290 | 8.100 |
| RSCJAN01 | 29156803 | 429659.00 | 515895.00 | 53.100 | 8.000 |
| RSCJAN01 | 29156901 | 429616.00 | 515958.00 | 53.440 | 15.500 |
| RSCJAN01 | 29156902 | 429647.50 | 515958.50 | 52.350 | 15.500 |
| RSCJAN01 | 29164001 | 429471.50 | 516010.50 | 42.760 | 6.710 |
| RSCJAN01 | 29164101 | 429496.50 | 516159.00 | 42.940 | 4.580 |
| RSCJAN01 | 29164201 | 429446.00 | 516219.00 | 44.740 | 5.180 |
| RSCJAN01 | 29165001 | 429566.50 | 516023.00 | 52.590 | 8.000 |
| RSCJAN01 | 29165002 | 429548.50 | 516005.50 | 51.840 | 15.500 |
| RSCJAN01 | 29165003 | 429534.00 | 516067.00 | 42.330 | 5.330 |
| RSCJAN01 | 29165004 | 429585.00 | 516075.50 | 41.840 | 6.700 |
| RSCJAN01 | 29165005 | 429539.50 | 516060.00 | 41.970 | 3.660 |
| RSCJAN01 | 29165006 | 429542.00 | 516071.00 | 42.120 | 4.100 |
| RSCJAN01 | 29165007 | 429590.50 | 516071.50 | 41.140 | 3.500 |
| RRPAPR95 | 29165008 | 429555.00 | 516072.00 | 42.200 | 2.000 |
| RSCJAN01 | 29165101 | 429518.50 | 516117.50 | 42.230 | 4.410 |
| RSCJAN01 | 29166001 | 429618.00 | 516008.50 | 53.200 | 18.500 |
| RSCJAN01 | 29166002 | 429666.50 | 516007.00 | 53.290 | 18.500 |
| RSCJAN01 | 29166003 | 429657.00 | 516088.50 | 41.770 | 6.710 |
| RSCJAN01 | 29166004 | 429641.50 | 516078.50 | 41.150 | 2.840 |
| RSCJAN01 | 29166101 | 429682.50 | 516105.00 | 42.130 | 6.710 |
| RSCJAN01 | 29167001 | 429731.50 | 516082.50 | 41.510 | 3.750 |
| RSCJAN01 | 29167002 | 429747.00 | 516086.00 | 41.910 | 3.300 |
| RSCJAN01 | 29167004 | 429722.50 | 516081.00 | 41.740 | 10.210 |
| RSCJAN01 | 29167101 | 429702.20 | 516124.00 | 44.550 | 9.140 |
| RSCJAN01 | 29167102 | 429781.50 | 516115.00 | 42.160 | 6.700 |
| RSCJAN01 | 29167103 | 429724.00 | 516104.00 | 50.500 | 18.440 |
| RSCJAN01 | 29168101 | 429869.50 | 516180.50 | 41.980 | 6.700 |
| RSCJAN01 | 29168102 | 429828.00 | 516157.20 | 41.760 | 2.840 |
| RRPAPR95 | 29168104 | 429861.00 | 516129.00 | 41.600 | 12.000 |
| RRPAPR95 | 29168105 | 429871.00 | 516119.00 | 41.860 | 11.000 |
| RRPAPR95 | 29168106 | 429883.00 | 516129.00 | 41.770 | 2.500 |
| RRPAPR95 | 29168107 | 429584.00 | 516133.00 | 42.390 | 1.200 |
| RSCJAN01 | 29168201 | 429811.00 | 516267.50 | 44.910 | 10.000 |
| RSCJAN01 | 29168202 | 429864.00 | 516288.00 | 47.310 | 10.000 |
| RSCJAN01 | 29168203 | 429892.00 | 516268.50 | 46.390 | 10.000 |
| RSCJAN01 | 29168301 | 429896.00 | 516353.00 | 52.370 | 10.000 |
| RSCJAN01 | 29168302 | 429833.50 | 516368.50 | 52.190 | 10.000 |
| RSCJAN01 | 29168303 | 429825.20 | 516322.50 | 50.100 | 10.000 |
| RSCJAN01 | 29168304 | 429891.00 | 516305.50 | 50.170 | 10.000 |
| RRPAPR95 | 29169102 | 429992.00 | 516169.00 | 42.910 | 3.400 |
| RSCJAN01 | 29169202 | 429908.50 | 516233.00 | 41.960 | 3.900 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| RRPAPR95 | 29169205 | 429964.00 | 516210.00 | 41.870 | 4.000 |
| RSCJAN01 | 30151901 | 430163.00 | 515950.00 | 43.250 | 4.570 |
| RSCJAN01 | 30152901 | 430275.00 | 515980.50 | 42.180 | 6.710 |
| RSCJAN01 | 30152902 | 430240.50 | 515957.00 | 42.390 | 2.130 |
| RSCJAN01 | 30152903 | 430272.00 | 515908.00 | 42.760 | 3.200 |
| RSCJAN01 | 30152904 | 430228.50 | 515991.50 | 42.270 | 3.050 |
| RRPAPR95 | 30152906 | 430207.00 | 515934.00 | 43.130 | 3.200 |
| RSCJAN01 | 30153801 | 430482.50 | 515838.50 | 42.320 | 3.660 |
| RSCJAN01 | 30153802 | 430415.00 | 515892.50 | 42.320 | 3.810 |
| RRPAPR95 | 30153803 | 430353.00 | 515863.00 | 42.820 | 4.500 |
| RSCJAN01 | 30153901 | 430335.00 | 515829.50 | 42.270 | 6.710 |
| RSCJAN01 | 30154601 | 430477.00 | 515682.00 | 43.200 | 4.570 |
| RSCJAN01 | 30154701 | 430463.50 | 515719.00 | 43.330 | 5.030 |
| RSCJAN01 | 30154702 | 430432.00 | 515777.00 | 43.450 | 1.220 |
| RRPAPR95 | 30154703 | 430447.00 | 515762.00 | 43.310 | 2.200 |
| RRPAPR95 | 30154704 | 430457.00 | 515787.00 | 43.130 | 1.500 |
| RSCJAN01 | 30154801 | 430406.50 | 515868.50 | 42.650 | 6.710 |
| RSCJAN01 | 30154802 | 430490.50 | 515812.50 | 43.050 | 6.710 |
| RSCJAN01 | 30154803 | 430401.00 | 515859.50 | 42.480 | 3.660 |
| RSCJAN01 | 30154901 | 430471.00 | 515922.50 | 44.760 | 1.910 |
| RSCJAN01 | 30154902 | 430443.50 | 515949.00 | 45.700 | 1.220 |
| RSCJAN01 | 30154903 | 430425.50 | 515937.00 | 43.370 | 1.280 |
| RSCJAN01 | 30154904 | 430441.00 | 515910.00 | 43.360 | 2.280 |
| RSCJAN01 | 30155801 | 430562.00 | 515814.50 | 42.620 | 6.710 |
| RSCJAN01 | 30157701 | 430716.50 | 515790.00 | 42.400 | 6.710 |
| RSCJAN01 | 30157702 | 430786.00 | 515767.00 | 43.630 | 6.860 |
| RSCJAN01 | 30157904 | 430763.50 | 515938.50 | 47.400 | 5.000 |
| RSCJAN01 | 30158701 | 430813.00 | 515759.50 | 43.570 | 6.710 |
| RSCJAN01 | 30158702 | 430892.00 | 515741.50 | 44.290 | 7.620 |
| RSCJAN01 | 30160001 | 430040.00 | 516094.00 | 50.500 | 14.000 |
| RSCJAN01 | 30160101 | 430082.00 | 516038.50 | 42.060 | 4.270 |
| RSCJAN01 | 30160102 | 430068.50 | 516033.00 | 42.370 | 4.570 |
| RRPAPR95 | 30160104 | 430002.00 | 516192.00 | 42.100 | 3.900 |
| RRPAPR95 | 30160105 | 430045.00 | 516186.00 | 42.120 | 3.700 |
| RRPAPR95 | 30160106 | 430075.00 | 516116.00 | 42.150 | 4.000 |
| RSCJAN01 | 30160107 | 430057.00 | 516107.00 | 44.450 | 9.000 |
| RSCJAN01 | 30160108 | 430068.50 | 516102.00 | 43.000 | 4.000 |
| RSCJAN01 | 30160109 | 430059.00 | 516118.50 | 43.000 | 4.000 |
| RSCJAN01 | 30160201 | 430076.00 | 516215.50 | 42.050 | 6.710 |
| RSCJAN01 | 30160202 | 430040.50 | 516247.00 | 42.060 | 3.500 |
| RRPAPR95 | 30160204 | 430013.00 | 516214.00 | 42.040 | 3.900 |
| RSCJAN01 | 30160301 | 430019.00 | 516399.00 | 51.920 | 4.000 |
| RSCJAN01 | 30160401 | 430030.00 | 516419.00 | 52.730 | 4.500 |
| RSCJAN01 | 30161001 | 430080.00 | 516068.00 | 42.380 | 6.710 |
| RSCJAN01 | 30161002 | 430116.00 | 516087.50 | 42.160 | 3.660 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| RSCJAN01 | 30161003 | 430177.50 | 516016.00 | 42.960 | 3.280 |
| RRPAPR95 | 30161004 | 430192.00 | 516036.00 | 42.390 | 4.000 |
| RRPAPR95 | 30161005 | 430129.00 | 516018.00 | 41.760 | 3.800 |
| RSCJAN01 | 30161101 | 430128.20 | 516146.00 | 42.110 | 6.710 |
| RSCJAN01 | 30161102 | 430100.50 | 516160.00 | 42.290 | 4.880 |
| RSCJAN01 | 31150701 | 431015.00 | 515728.50 | 42.470 | 4.880 |
| RSCJAN01 | 31151701 | 431111.00 | 515730.00 | 42.600 | 4.880 |
| RSCJAN01 | 31152701 | 431218.00 | 515707.50 | 43.100 | 4.880 |
| RSCJAN01 | 31152702 | 431283.00 | 515742.50 | 44.120 | 7.000 |
| RSCJAN01 | 31153701 | 431313.00 | 515710.00 | 42.540 | 4.880 |
| RSCJAN01 | 31153702 | 431396.00 | 515778.00 | 42.250 | 4.880 |
| RSCJAN01 | 31153801 | 431376.00 | 515829.50 | 43.900 | 7.000 |
| RSCJAN01 | 31154601 | 431471.50 | 515670.00 | 43.970 | 4.880 |
| RSCJAN01 | 31154802 | 431471.50 | 515824.00 | 42.730 | 4.880 |
| RSCJAN01 | 31154901 | 431480.50 | 515920.50 | 43.430 | 6.500 |
| RSCJAN01 | 31155802 | 431543.00 | 515893.00 | 42.980 | 4.880 |
| RSCJAN01 | 31155902 | 431578.50 | 515970.20 | 43.690 | 6.500 |
| RSCJAN01 | 31156901 | 431521.00 | 515968.00 | 43.560 | 4.880 |
| RSCJAN01 | 31164404 | 431453.50 | 516427.50 | 46.200 | 5.000 |
| RSCJAN01 | 31164405 | 431442.00 | 516424.00 | 46.190 | 5.000 |
| RSCJAN01 | 31164406 | 431435.00 | 516426.50 | 43.130 | 5.000 |
| RSCJAN01 | 31164407 | 431430.00 | 516438.00 | 46.120 | 5.000 |
| RSCJAN01 | 31164501 | 431488.00 | 516503.00 | 47.960 | 7.000 |
| RSCJAN01 | 31164701 | 431491.00 | 516763.50 | 46.600 | 2.000 |
| RSCJAN01 | 31164702 | 431495.50 | 516748.00 | 46.650 | 2.100 |
| RSCJAN01 | 31165401 | 431502.00 | 516430.00 | 46.890 | 5.400 |
| RSCJAN01 | 31165402 | 431559.00 | 516435.00 | 46.240 | 5.900 |
| RSCJAN01 | 31165501 | 431588.00 | 516506.00 | 44.530 | 4.250 |
| RSCJAN01 | 31165502 | 431531.00 | 516505.50 | 47.240 | 6.000 |
| RSCJAN01 | 31165701 | 431520.00 | 516769.50 | 46.550 | 2.200 |
| RSCJAN01 | 31165702 | 431510.00 | 516781.00 | 46.550 | 2.440 |
| RSCJAN01 | 31165703 | 431515.60 | 516771.50 | 46.550 | 2.100 |
| RSCJAN01 | 31165704 | 431501.00 | 516776.00 | 46.550 | 2.100 |
| RSCJAN01 | 31165705 | 431503.50 | 516764.50 | 46.550 | 2.440 |
| RSCJAN01 | 31165706 | 431506.00 | 516741.00 | 46.650 | 2.440 |
| RSCJAN01 | 31165707 | 431519.00 | 516747.50 | 46.350 | 3.960 |
| RSCJAN01 | 31165708 | 431533.00 | 516753.00 | 46.350 | 3.960 |
| RSCJAN01 | 31165709 | 431529.00 | 516762.50 | 46.350 | 3.960 |
| RSCJAN01 | 31166001 | 431622.00 | 516063.00 | 43.320 | 4.880 |
| RSCJAN01 | 31166003 | 431670.50 | 516035.50 | 43.450 | 6.500 |
| RSCJAN01 | 31166101 | 431617.50 | 516165.50 | 43.550 | 4.880 |
| RSCJAN01 | 31166103 | 431672.50 | 516162.00 | 44.230 | 6.500 |
| RSCJAN01 | 31166202 | 431611.50 | 516266.00 | 43.810 | 5.030 |
| RSCJAN01 | 31166203 | 431633.00 | 516267.00 | 43.950 | 6.500 |
| RSCJAN01 | 31166301 | 431608.00 | 516393.00 | 44.380 | 5.030 |

| Project Ref | Borehole Number | Coordinates | | G.Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| RSCJAN01 | 31166401 | 431611.50 | 516434.80 | 44.410 | 6.850 |
| RSCJAN01 | 31166402 | 431623.50 | 516477.50 | 43.970 | 6.850 |
| RSCJAN01 | 31166501 | 431645.50 | 516503.00 | 43.670 | 6.850 |
| NRASOLID | 31167801 | 431741.00 | 516862.00 | 45.720 | 125.580 |

**Total Number of Boreholes = 454 No**

## APPENDIX 12 - Borehole Data : River Corridor (Sheet 11 of 11)

| Project Ref | Borehole Number | Coordinates | | G. Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| BGSMA40 | 20106901 | 420670.00 | 510920.00 | 80.500 | 11.600 |
| BGSSLS | 20152601 | 420294.00 | 515604.00 | 59.070 | 67.060 |
| BGSMA40 | 20156901 | 420610.00 | 515950.00 | 60.400 | 8.200 |
| BGSSLS | 21137401 | 421760.00 | 513460.00 | 77.110 | 43.840 |
| BGSSLS | 21150801 | 421037.00 | 515824.00 | 59.390 | 3.000 |
| BGSSLS | 21150802 | 421046.00 | 515894.00 | 58.130 | 5.000 |
| BGSSLS | 21155701 | 421579.00 | 515789.00 | 70.350 | 10.670 |
| BGSMA40 | 21156501 | 421655.00 | 515570.00 | 52.700 | 4.500 |
| BGSSLS | 21156701 | 421603.00 | 515781.00 | 29.420 | 9.140 |
| BGSMA40 | 21185601 | 421595.00 | 518620.00 | 80.800 | 2.100 |
| BGSSLS | 21228501 | 421864.00 | 522525.00 | 182.880 | 47.240 |
| BGSSLS | 21229501 | 421900.00 | 522500.00 | 182.880 | 37.130 |
| BGSMA40 | 22151001 | 422173.00 | 515030.00 | 51.500 | 6.800 |
| DBCSOLID | 22155301 | 422546.50 | 515328.00 | 63.970 | 4.000 |
| NRASOLID | 22168901 | 422832.00 | 516936.00 | 60.960 | 32.180 |
| BGSMA40 | 22175601 | 422560.00 | 517680.00 | 68.600 | 3.400 |
| BGSSLS | 22238301 | 422807.00 | 523362.00 | 169.470 | 37.190 |
| BGSMA40 | 23175001 | 423545.00 | 517020.00 | 60.400 | 12.700 |
| BGSSLS | 24112601 | 424260.00 | 511690.00 | 70.190 | 8.840 |
| BGSSLS | 24112701 | 424290.00 | 511750.00 | 69.990 | 7.700 |
| BGSSLS | 24113701 | 424390.00 | 511780.00 | 71.710 | 9.220 |
| BGSSLS | 24113702 | 424310.00 | 511750.00 | 70.670 | 7.320 |
| BGSSLS | 24115801 | 424510.00 | 511820.00 | 69.640 | 3.100 |
| BGSSLS | 24115802 | 424520.00 | 511800.00 | 69.400 | 2.440 |
| BGSSLS | 24115803 | 424500.00 | 511850.00 | 69.640 | 8.080 |
| BGSSLS | 24116801 | 424650.00 | 511870.00 | 67.100 | 6.910 |
| BGSSLS | 24127301 | 424748.00 | 512318.00 | 75.950 | 80.000 |
| BGSSLS | 24130001 | 424090.00 | 513080.00 | 47.240 | 10.360 |
| BGSSLS | 24135301 | 424587.00 | 513348.00 | 38.010 | 10.670 |
| BGSSLS | 24135401 | 424596.00 | 513438.00 | 38.100 | 14.480 |
| BGSSLS | 24135402 | 424558.00 | 513420.00 | 38.100 | 13.870 |
| BGSSLS | 24136301 | 424617.00 | 513362.00 | 38.100 | 11.280 |
| BGSSLS | 24137802 | 424710.00 | 513860.00 | 46.940 | 32.310 |
| NRASOLID | 24141201 | 424192.00 | 514219.00 | 51.820 | 78.940 |
| BGSSLS | 24149401 | 424981.00 | 514453.00 | 50.290 | 76.200 |
| BGSSLS | 24163401 | 424330.00 | 516460.00 | 57.900 | 24.400 |
| BGSSLS | 24168301 | 424801.00 | 516347.00 | 50.290 | 158.800 |
| BGSSLS | 24223401 | 424380.00 | 522494.00 | 152.250 | 5.870 |
| BGSSLS | 24226901 | 424658.00 | 522925.00 | 139.530 | 2.500 |
| BGSSLS | 24229401 | 424980.00 | 522246.00 | 140.210 | 33.530 |
| BGSSLS | 24229801 | 424917.00 | 522853.00 | 138.710 | 5.500 |
| BGSSLS | 25076101 | 425690.00 | 507160.00 | 64.620 | 60.960 |
| BGSSLS | 25097701 | 425708.00 | 509706.00 | 57.910 | 40.230 |
| NRASOLID | 25144001 | 425485.00 | 514029.00 | 44.200 | 50.290 |
| NRASOLID | 25145101 | 425506.00 | 514148.00 | 45.720 | 38.400 |

| Project Ref | Borehole Number | Coordinates | | G. Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| NRASOLID | 25145102 | 425523.00 | 514195.00 | 45.720 | 101.190 |
| NRASOLID | 25146201 | 425679.00 | 514231.00 | 50.290 | 90.830 |
| NRASOLID | 25146401 | 425675.00 | 514416.00 | 51.820 | 69.190 |
| NRASOLID | 25172601 | 425288.00 | 517675.00 | 60.050 | 44.200 |
| NRASOLID | 25173701 | 425301.00 | 517709.00 | 57.910 | 56.920 |
| NRASOLID | 25183901 | 425340.00 | 518930.00 | 82.300 | 32.920 |
| NRASOLID | 25191801 | 425199.00 | 519807.00 | 99.210 | 59.820 |
| NRASOLID | 25191901 | 425186.00 | 519938.00 | 95.710 | 51.820 |
| BGSSLS | 25212801 | 425208.00 | 521886.00 | 106.180 | 6.800 |
| BGSSLS | 25221701 | 425128.00 | 522758.00 | 135.280 | 4.500 |
| DIRECT | 25222701 | 425209.00 | 522797.00 | 135.140 | 5.000 |
| DIRECT | 25222901 | 425225.00 | 522906.00 | 131.810 | 4.300 |
| BGSSLS | 25223101 | 425327.00 | 522139.00 | 116.700 | 3.100 |
| BGSSLS | 25223501 | 425346.00 | 522506.00 | 129.150 | 7.200 |
| DIRECT | 25226501 | 425610.00 | 522593.00 | 119.840 | 5.000 |
| DIRECT | 25227501 | 425741.00 | 522533.50 | 114.980 | 3.000 |
| DIRECT | 26090901 | 426092.00 | 509920.00 | 51.820 | 51.210 |
| BGSSLS | 26116801 | 426680.00 | 511820.00 | 38.100 | 0.000 |
| NRASOLID | 26150601 | 426080.00 | 515660.00 | 48.830 | 39.620 |
| FAVSEP92 | 26177301 | 426747.00 | 517352.50 | 71.330 | 10.600 |
| FAVSEP92 | 26179201 | 426928.00 | 517295.00 | 60.580 | 7.550 |
| FAVSEP92 | 26179401 | 426922.50 | 517423.00 | 66.040 | 7.900 |
| BGSSLS | 26182601 | 426208.00 | 518635.00 | 80.770 | 32.310 |
| BGSSOLID | 27109001 | 427997.00 | 510070.00 | 33.500 | 54.400 |
| FAVSEP92 | 27170501 | 427090.00 | 517557.50 | 68.310 | 9.450 |
| BGSSLS | 27171601 | 427190.00 | 517690.00 | 68.580 | 24.380 |
| FAVSEP92 | 27173601 | 427365.00 | 517602.00 | 65.880 | 7.950 |
| BGSSLS | 27174001 | 427448.00 | 517000.00 | 67.060 | 32.920 |
| FAVSEP92 | 27180101 | 427086.00 | 518193.50 | 75.880 | 12.000 |
| BGSSLS | 27201301 | 427120.00 | 520371.00 | 77.950 | 84.580 |
| STGRAVE | 27219801 | 427915.00 | 521868.00 | 86.000 | 17.100 |
| STGRAVE | 27219901 | 427927.00 | 521949.00 | 89.330 | 20.000 |
| STGRAVE | 27219902 | 427971.00 | 521919.00 | 88.750 | 15.200 |
| BGSSLS | 27220501 | 427032.00 | 522533.00 | 92.960 | 16.760 |
| BGSSLS | 27222301 | 427209.00 | 522380.00 | 91.060 | 6.000 |
| BGSSLS | 27222302 | 427290.00 | 522370.00 | 90.580 | 5.150 |
| BGSSLS | 27222303 | 427246.00 | 522333.00 | 91.860 | 5.500 |
| BGSSLS | 27222304 | 427221.00 | 522397.00 | 90.690 | 6.000 |
| BGSSLS | 27222305 | 427246.00 | 522394.00 | 90.550 | 5.950 |
| BGSSLS | 27222404 | 427255.00 | 522412.00 | 90.240 | 6.000 |
| BGSSLS | 27222405 | 427256.00 | 522432.00 | 89.980 | 6.250 |
| BGSSLS | 27222407 | 427255.00 | 522454.00 | 90.150 | 7.300 |
| BGSSLS | 27222408 | 427226.00 | 522427.00 | 90.370 | 6.550 |
| BGSSLS | 27222409 | 427251.00 | 522424.00 | 90.280 | 6.100 |
| BGSSLS | 27223101 | 427313.00 | 522194.00 | 93.120 | 5.030 |

**APPENDIX 13 - Borehole Data : Darlington Sub Region (Sheet 2 of 6)**

| Project Ref | Borehole Number | Coordinates | | G. Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| BGSSLS | 27223301 | 427327.00 | 522323.00 | 90.850 | 4.000 |
| BGSSLS | 27223402 | 427335.00 | 522406.00 | 89.480 | 5.550 |
| BGSSLS | 27226101 | 427645.00 | 522190.00 | 90.590 | 11.130 |
| BGSSLS | 27226301 | 427686.00 | 522354.00 | 88.790 | 10.060 |
| BGSSLS | 27228601 | 427847.00 | 522671.00 | 86.250 | 4.000 |
| BGSSLS | 27228602 | 427895.00 | 522671.00 | 85.250 | 4.200 |
| BGSSLS | 27228603 | 427874.00 | 522649.00 | 85.750 | 4.000 |
| BGSSLS | 27228604 | 427893.00 | 522624.00 | 85.650 | 4.100 |
| BGSSLS | 27228605 | 427844.00 | 522622.00 | 86.250 | 4.000 |
| STGRAVE | 27229001 | 427937.00 | 522017.00 | 89.670 | 20.000 |
| STGRAVE | 27229002 | 427995.00 | 522080.00 | 91.290 | 16.600 |
| STGRAVE | 27229003 | 427978.00 | 522002.00 | 90.920 | 22.100 |
| STGRAVE | 27229101 | 427942.00 | 522106.00 | 90.900 | 20.000 |
| BGSSLS | 28061801 | 428120.00 | 506810.00 | 53.340 | 73.150 |
| BGSSLS | 28099001 | 428925.00 | 509003.00 | 42.120 | 50.900 |
| BGSSLS | 28108201 | 428879.00 | 510207.00 | 29.700 | 8.220 |
| BGSSLS | 28109101 | 428921.51 | 510197.00 | 30.020 | 9.740 |
| NRASOLID | 28113201 | 428340.00 | 511210.00 | 32.200 | 80.790 |
| DBCSOLID | 28133301 | 428331.00 | 513386.00 | 38.640 | 101.500 |
| BGSSLS | 28147302 | 428756.00 | 514339.00 | 48.770 | 75.920 |
| BGSSLS | 28149205 | 428963.00 | 514224.50 | 37.810 | 51.820 |
| CORJAN87 | 28149503 | 428962.00 | 514540.50 | 44.450 | 40.250 |
| BGSSLS | 28152301 | 428263.00 | 515328.00 | 51.810 | 86.500 |
| BGSSLS | 28166701 | 428650.00 | 516780.00 | 58.600 | 49.530 |
| BGSSLS | 28210301 | 428248.00 | 521314.00 | 66.140 | 110.950 |
| STGRAVE | 28210801 | 428017.00 | 521840.00 | 86.500 | 20.000 |
| STGRAVE | 28210901 | 428074.00 | 521929.00 | 88.100 | 21.500 |
| STGRAVE | 28211801 | 428186.00 | 521803.00 | 77.000 | 20.000 |
| STGRAVE | 28211802 | 428157.00 | 521874.00 | 84.000 | 9.500 |
| STGRAVE | 28211901 | 428145.00 | 521987.00 | 89.370 | 22.100 |
| BGSSLS | 28212301 | 428290.00 | 521370.00 | 66.470 | 58.240 |
| STGRAVE | 28212801 | 428257.00 | 521839.00 | 78.250 | 20.000 |
| STGRAVE | 28213801 | 428309.00 | 521869.00 | 78.750 | 20.000 |
| BGSSLS | 28215501 | 428598.00 | 521547.00 | 79.300 | 8.690 |
| BGSSLS | 28215702 | 428538.00 | 521775.00 | 64.530 | 2.820 |
| BGSSLS | 28215703 | 428547.00 | 521728.00 | 71.710 | 2.640 |
| BGSSLS | 28215801 | 428533.00 | 521842.00 | 64.100 | 5.510 |
| STGRAVE | 28220001 | 428062.00 | 522033.00 | 92.180 | 21.500 |
| STGRAVE | 28220002 | 428092.00 | 522076.00 | 90.900 | 11.500 |
| STGRAVE | 28220003 | 428068.00 | 522055.00 | 91.630 | 20.500 |
| STGRAVE | 28220101 | 428034.00 | 522115.00 | 90.230 | 20.000 |
| STGRAVE | 28221002 | 428153.00 | 522074.00 | 90.640 | 20.000 |
| STGRAVE | 28221003 | 428117.00 | 522050.00 | 91.620 | 20.500 |
| STGRAVE | 28221101 | 428123.00 | 522100.00 | 89.130 | 20.000 |
| STGRAVE | 28226401 | 428673.00 | 522490.00 | 81.020 | 40.000 |

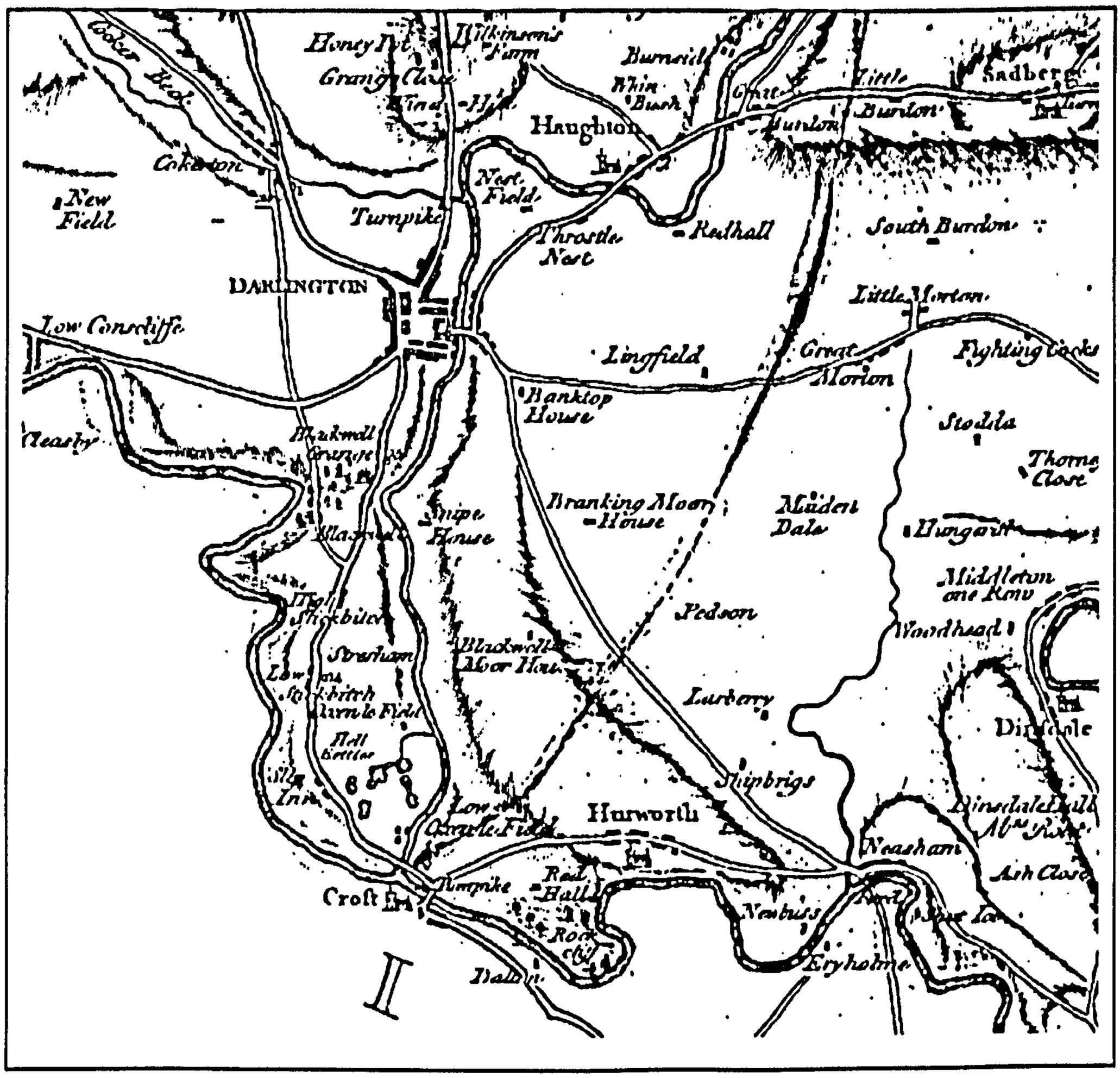
| Project Ref | Borehole Number | Coordinates | | G. Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| STGRAVE | 28226402 | 428661.00 | 522470.00 | 80.780 | 41.000 |
| STGRAVE | 28226403 | 428658.00 | 522444.00 | 82.500 | 42.000 |
| STGRAVE | 28226404 | 428697.00 | 522499.00 | 82.060 | 42.000 |
| STGRAVE | 28227501 | 428724.00 | 522507.00 | 82.500 | 42.000 |
| STGRAVE | 28227502 | 428749.00 | 522513.00 | 82.500 | 42.000 |
| STGRAVE | 28227503 | 428778.00 | 522517.00 | 83.430 | 43.000 |
| BGSSLS | 28230701 | 428089.00 | 523799.00 | 85.000 | 62.480 |
| BGSSLS | 29081201 | 429130.00 | 508200.00 | 51.050 | 62.580 |
| BGSSOLID | 29086101 | 429632.00 | 508158.00 | 51.510 | 76.200 |
| BGSSOLID | 29090501 | 429020.00 | 509530.00 | 29.300 | 165.300 |
| DBCSOLID | 29122902 | 429294.00 | 512967.00 | 43.610 | 105.000 |
| BGSSOLID | 29129801 | 429900.00 | 512870.00 | 42.000 | 68.820 |
| DBCSOLID | 29131104 | 429108.00 | 513198.00 | 40.090 | 93.000 |
| DBCSOLID | 29134201 | 429464.00 | 513214.00 | 41.480 | 108.000 |
| BGSSLS | 29149201 | 429989.00 | 514247.00 | 47.500 | 74.980 |
| NRASOLID | 29194301 | 429450.00 | 519300.00 | 56.100 | 61.260 |
| BGSSLS | 29210901 | 429005.00 | 521923.00 | 91.440 | 41.760 |
| BGSSLS | 29214901 | 429430.00 | 521994.00 | 95.400 | 26.520 |
| STGRAVE | 29220001 | 429027.00 | 522076.00 | 92.500 | 53.000 |
| STGRAVE | 29220002 | 429012.00 | 522069.00 | 92.500 | 53.000 |
| BGSSLS | 29220301 | 429097.00 | 522382.00 | 83.820 | 15.240 |
| BGSSLS | 29229001 | 429930.00 | 522055.00 | 94.490 | 43.280 |
| BGSSLS | 30092301 | 430230.00 | 509350.00 | 32.990 | 129.080 |
| BGSMA111 | 30103501 | 430352.00 | 510580.00 | 34.100 | 16.000 |
| BGSSLS | 30122607 | 430294.00 | 512604.00 | 38.420 | 73.800 |
| BGSSLS | 30122702 | 430206.00 | 512753.00 | 40.180 | 47.300 |
| DBCSOLID | 30139301 | 430933.00 | 513369.00 | 44.810 | 70.600 |
| BGSSLS | 30175401 | 430500.00 | 517400.00 | 64.010 | 76.200 |
| BGSSLS | 30222201 | 430255.00 | 522258.00 | 80.600 | 0.000 |
| BGSSLS | 31081601 | 431160.00 | 508640.00 | 22.860 | 6.500 |
| BGSMA111 | 31098701 | 431840.00 | 509765.00 | 25.600 | 12.500 |
| BGSSLS | 31105301 | 431550.00 | 510360.00 | 28.600 | 104.320 |
| BGSMA111 | 31105401 | 431510.00 | 510445.00 | 25.900 | 7.500 |
| BGSSLS | 31139402 | 431942.00 | 513475.00 | 48.600 | 42.000 |
| BGSSLS | 31152703 | 431270.00 | 515770.00 | 45.400 | 54.170 |
| NRASOLID | 31167801 | 431742.00 | 516862.00 | 45.720 | 79.860 |
| NRASOLID | 31201201 | 431197.00 | 520202.00 | 72.880 | 76.200 |
| NRASOLID | 31201801 | 431198.00 | 520841.00 | 83.820 | 126.800 |
| NRASOLID | 31203601 | 431330.00 | 520670.00 | 74.400 | 104.240 |
| DIRECT | 31220601 | 431029.00 | 522668.00 | 93.570 | 97.540 |
| NRASOLID | 31224701 | 431433.00 | 522720.00 | 89.610 | 78.330 |
| BGSSLS | 32061001 | 432180.00 | 506020.00 | 51.200 | 51.820 |
| BGSSLS | 32070601 | 432060.00 | 507640.00 | 51.210 | 51.820 |
| BGSSLS | 32080701 | 432090.00 | 508725.00 | 37.800 | 203.000 |
| BGSSLS | 32094801 | 432416.00 | 509806.00 | 22.860 | 46.020 |

| Project Ref | Borehole Number | Coordinates | | G. Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| BGSMA111 | 32104401 | 432405.00 | 510450.00 | 22.300 | 13.500 |
| BGSSLS | 32112401 | 432125.00 | 511490.00 | 35.660 | 44.680 |
| BGSSLS | 32130601 | 432047.00 | 513628.00 | 50.000 | 43.000 |
| BGSSLS | 32131401 | 432119.00 | 513429.00 | 48.600 | 42.300 |
| DBCSOLID | 32133401 | 432380.00 | 513467.00 | 49.570 | 24.500 |
| NRASOLID | 32214801 | 432495.00 | 521898.00 | 106.680 | 94.490 |
| BGSSLS | 33103501 | 433320.00 | 510560.00 | 44.000 | 39.620 |
| BGSSOLID | 33112301 | 433280.00 | 511390.00 | 54.300 | 132.110 |
| BGSSLS | 33126001 | 433610.00 | 512100.00 | 51.210 | 73.610 |
| BGSSLS | 33216801 | 433642.00 | 521825.00 | 91.400 | 68.880 |
| NRASOLID | 33217501 | 433744.00 | 521562.00 | 71.790 | 79.860 |
| BGSMA44 | 33292401 | 433270.00 | 529450.00 | 75.900 | 17.000 |
| BGSSLS | 34086101 | 434664.00 | 508118.00 | 45.110 | 60.960 |
| BGSSLS | 34099401 | 434956.00 | 509423.00 | 17.940 | 19.810 |
| BGSMA111 | 34108701 | 434870.00 | 510700.00 | 20.400 | 9.500 |
| BGSMA111 | 34116701 | 434660.00 | 511700.00 | 18.300 | 9.500 |
| BGSSOLID | 34124001 | 434400.00 | 512000.00 | 11.000 | 135.760 |
| BGSSOLID | 34162504 | 434228.00 | 516534.00 | 45.420 | 54.170 |
| BGSSLS | 34217701 | 434710.00 | 521790.00 | 64.270 | 109.740 |
| NRASOLID | 34228901 | 434894.00 | 522982.00 | 69.100 | 74.980 |
| BGSSLS | 34247101 | 434749.00 | 524174.00 | 70.100 | 50.370 |
| BGSMA111 | 35071301 | 435178.00 | 507380.00 | 15.500 | 20.000 |
| BGSSLS | 35079801 | 435915.00 | 507820.00 | 45.720 | 57.910 |
| BGSSLS | 35084301 | 435457.00 | 508375.00 | 50.290 | 6.250 |
| BGSSLS | 35085301 | 435567.00 | 508319.00 | 46.930 | 47.780 |
| BGSSLS | 35085801 | 435585.00 | 508804.00 | 43.590 | 60.960 |
| BGSSLS | 35091701 | 435167.00 | 509771.00 | 15.240 | 21.340 |
| BGSMA111 | 35113301 | 435330.00 | 511365.00 | 25.300 | 11.500 |
| BGSSLS | 35120302 | 435005.00 | 512339.00 | 24.380 | 21.340 |
| BGSSLS | 35121201 | 435189.00 | 512263.00 | 27.430 | 21.340 |
| BGSSLS | 35121202 | 435182.00 | 512214.00 | 10.670 | 6.100 |
| BGSSLS | 35121203 | 435180.00 | 512299.00 | 32.920 | 27.430 |
| BGSSLS | 35122101 | 435278.00 | 512138.00 | 10.670 | 6.100 |
| BGSSLS | 35123201 | 435342.00 | 512209.00 | 31.390 | 27.430 |
| BGSSLS | 35189501 | 435964.00 | 518562.00 | 49.070 | 195.680 |
| NRASOLID | 35233101 | 435390.00 | 523160.00 | 49.350 | 75.840 |
| NRASOLID | 35234101 | 435400.00 | 523130.00 | 49.540 | 100.630 |
| NRASOLID | 35234401 | 435480.00 | 523450.00 | 49.340 | 72.500 |
| NRASOLID | 35235402 | 435500.00 | 523450.00 | 48.460 | 115.000 |
| BGSSLS | 35235501 | 435540.00 | 523558.00 | 39.220 | 74.000 |
| DIRECT | 35235502 | 435555.00 | 523521.00 | 38.250 | 73.000 |
| BGSSLS | 36063201 | 436340.00 | 506240.00 | 45.720 | 46.940 |
| BGSSLS | 36078701 | 436800.00 | 507780.00 | 48.770 | 0.000 |
| BGSSLS | 36098201 | 436821.00 | 509242.00 | 26.670 | 20.880 |
| BGSSLS | 36098301 | 436863.00 | 509309.00 | 35.050 | 70.410 |

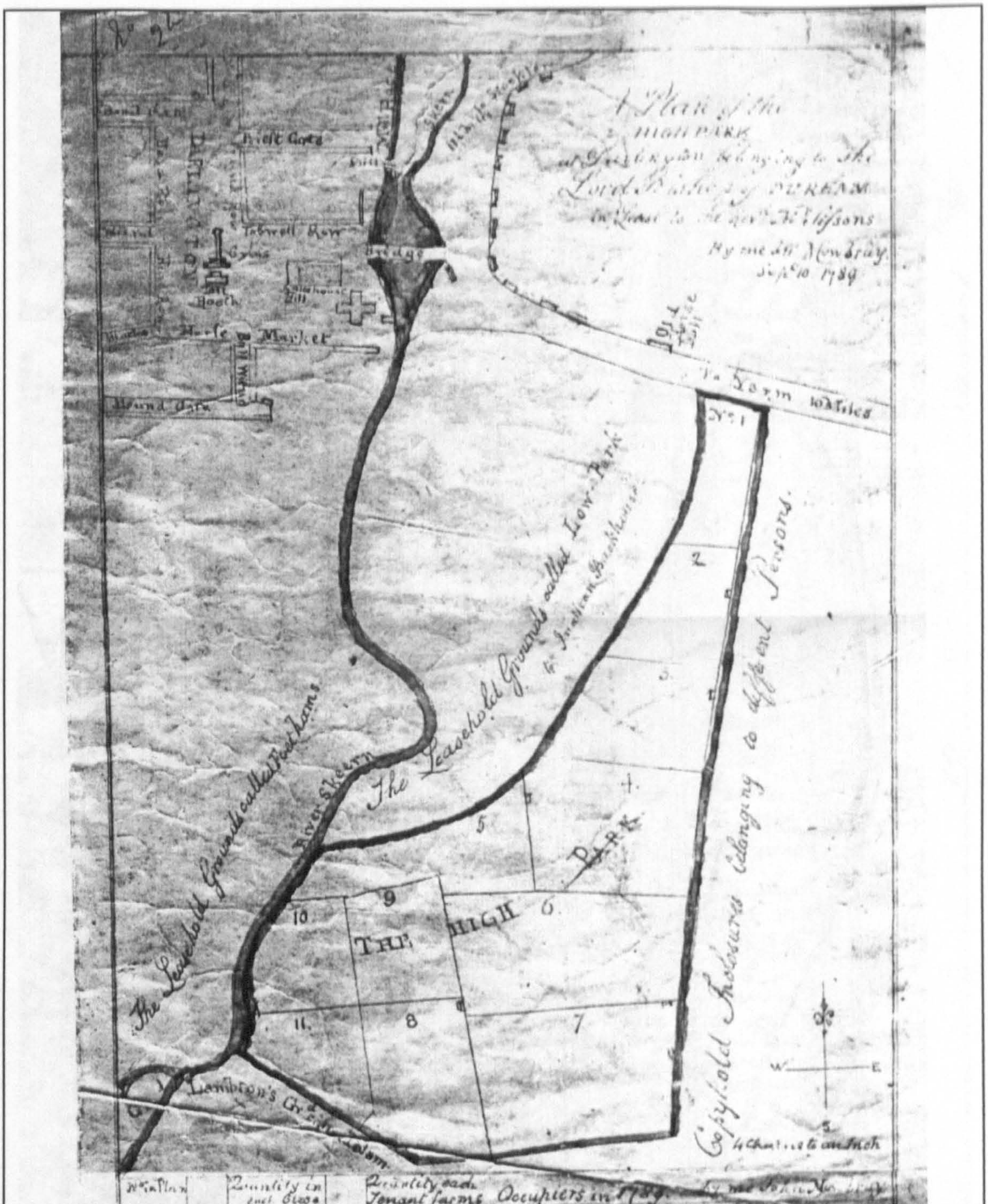
| Project Ref | Borehole Number | Coordinates | | G. Level (m) | Depth (m) |
|---|---|---|---|---|---|
| | | E | N | | |
| BGSMA111 | 36114001 | 436460.00 | 511050.00 | 11.900 | 18.500 |
| BGSSLS | 37066901 | 437650.00 | 506980.00 | 47.850 | 55.630 |
| BGSMA111 | 37101701 | 437150.00 | 510785.00 | 8.300 | 10.000 |
| BGSSLS | 37118101 | 437835.00 | 511116.00 | 30.480 | 92.660 |
| BGSSLS | 37119001 | 437924.00 | 511096.00 | 30.480 | 69.800 |
| BGSSLS | 37166301 | 437600.00 | 516371.00 | 40.840 | 49.500 |
| BGSSLS | 37184101 | 437456.00 | 518134.00 | 49.680 | 91.440 |
| NRASOLID | 37229601 | 437906.00 | 522608.00 | 30.330 | 5.560 |
| BGSSLS | 38083501 | 438385.00 | 508585.00 | 33.530 | 50.900 |
| BGSMA111 | 38108501 | 438880.00 | 510520.00 | 7.000 | 15.000 |
| BGSSLS | 38111001 | 438178.00 | 511091.00 | 32.000 | 95.710 |
| BGSSLS | 39102101 | 439229.00 | 510144.00 | 16.760 | 44.200 |
| BGSMA111 | 39108401 | 439800.00 | 510440.00 | 7.000 | 15.000 |
| BGSSLS | 39161501 | 439100.00 | 516500.00 | 30.580 | 80.000 |
| BGSSOLID | 39201801 | 439130.00 | 520840.00 | 44.810 | 100.510 |

**Total Number of Boreholes = 240 No**

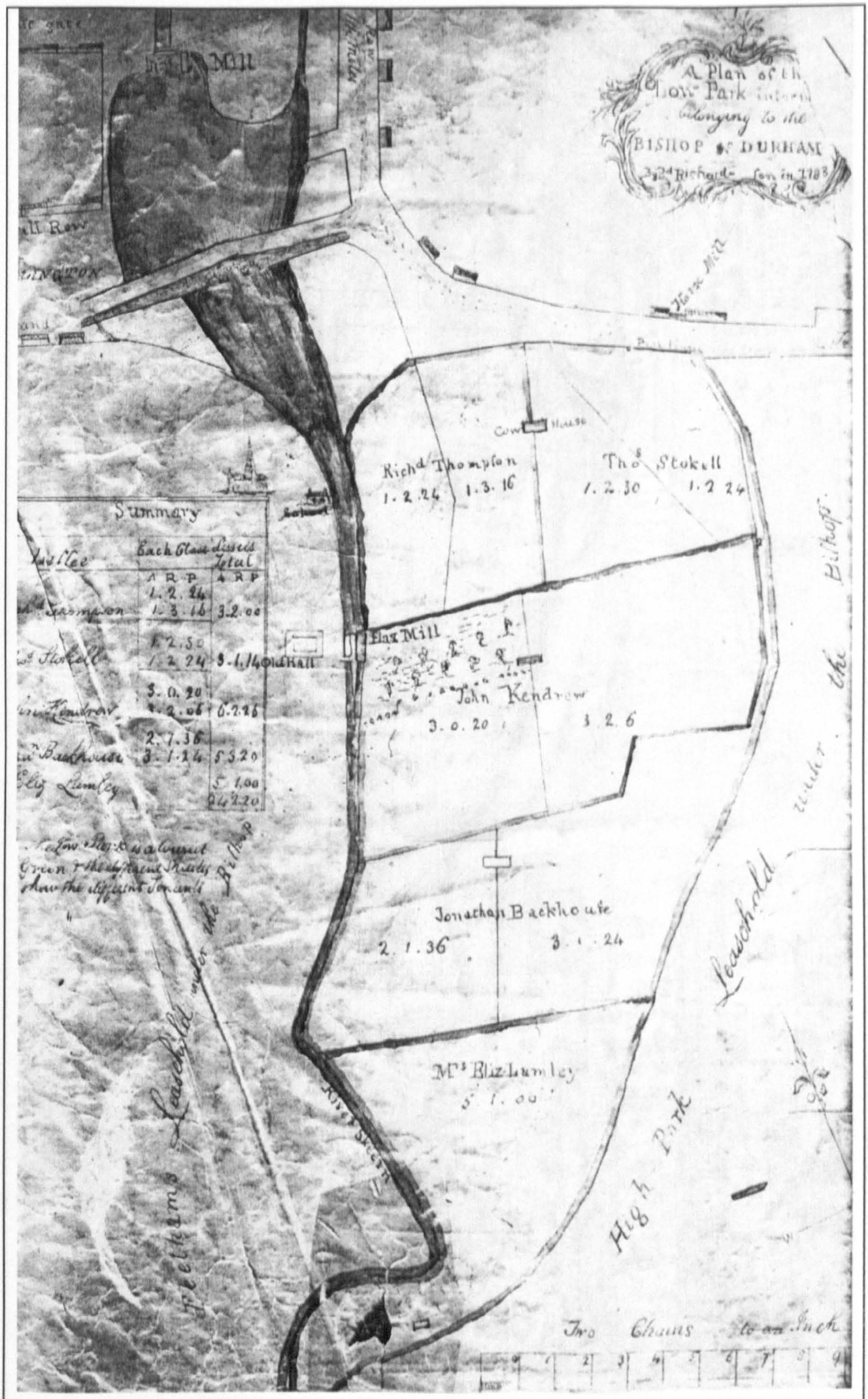
**APPENDIX 13 - Borehole Data : Darlington Sub Region (Sheet 6 of 6)**




**APPENDIX 14 - Jeffrey's Map of Durham c1770**

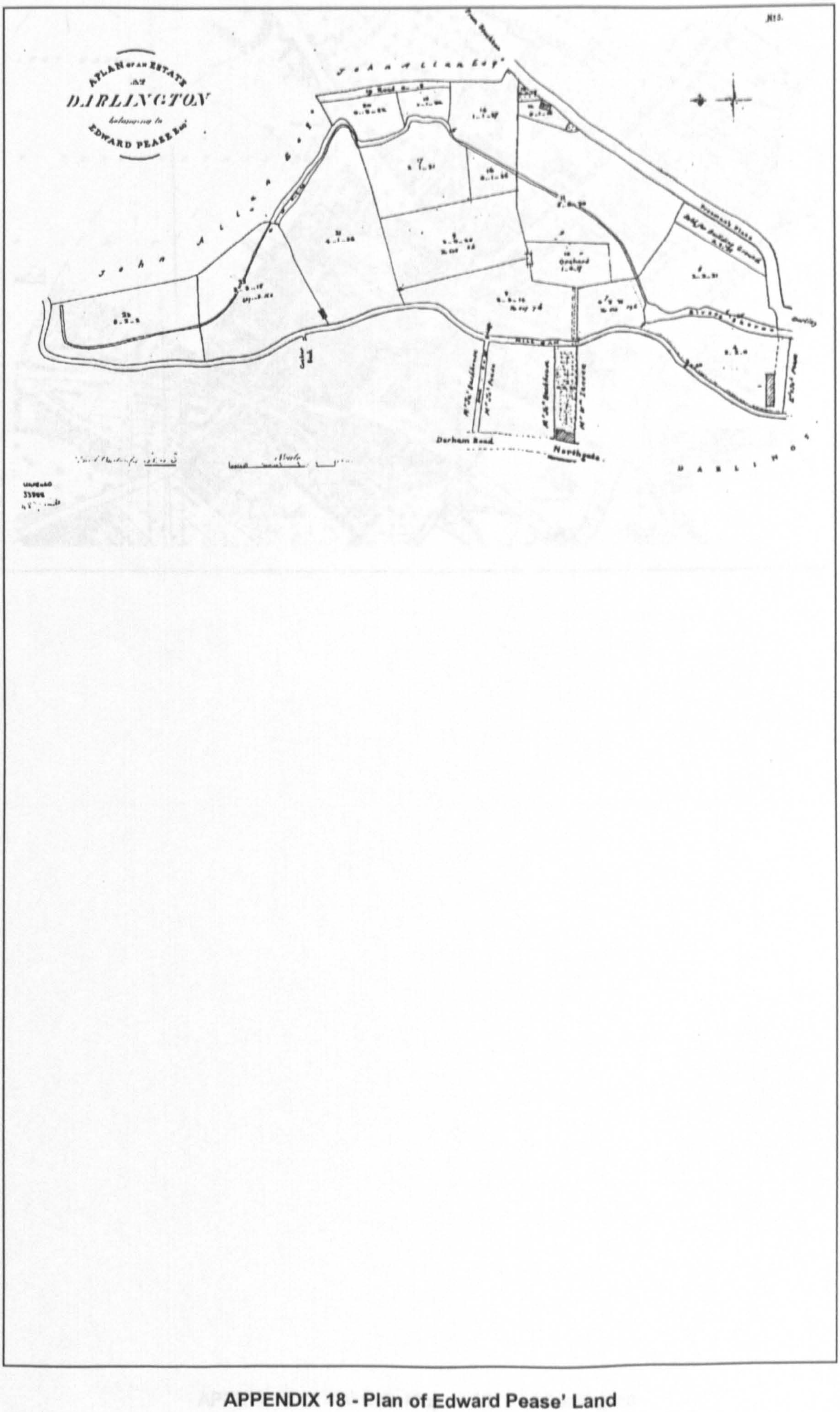



**APPENDIX 15 - Mowbray's Survey of High Parks of 1776**

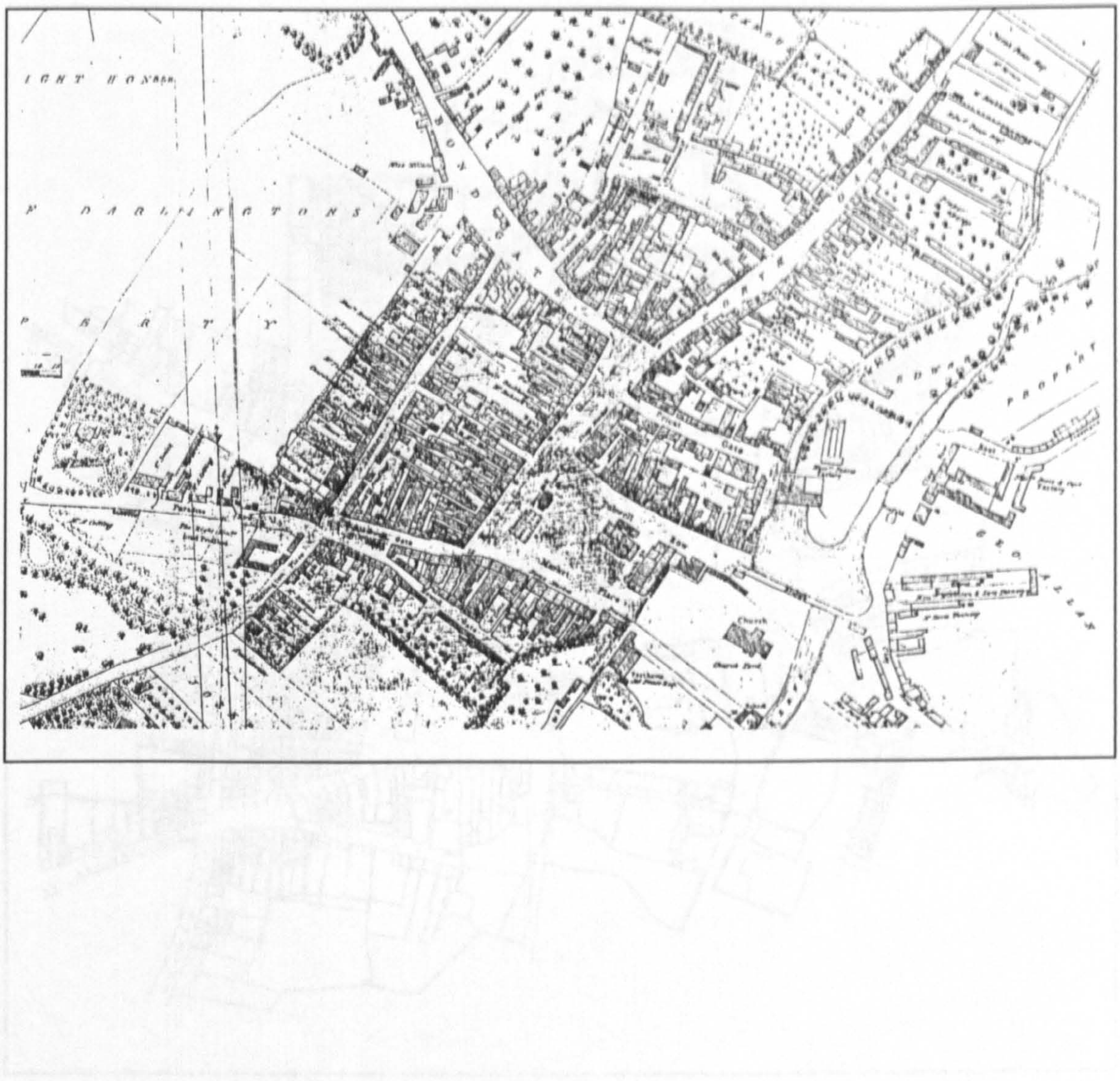



**APPENDIX 16 - Richardson's Survey of Low Parks of 1778**

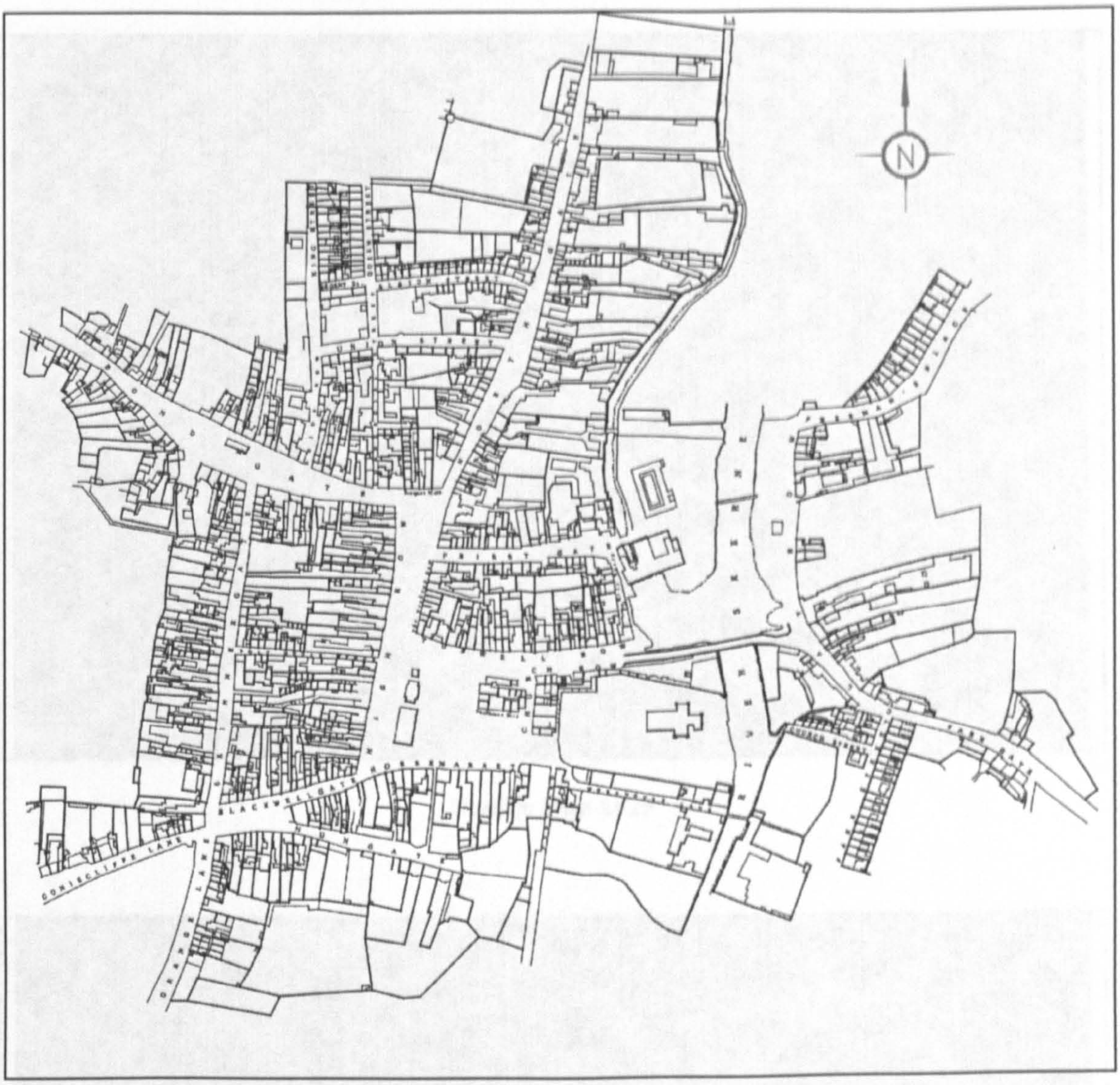
Barrington Road
Tidwell Road
Church Yard
Church
Round Yard
Bridge
Hall
Pond
Stocks
Gate
Gate
Gate




**APPENDIX 18 - Plan of Edward Pease' Land**



**APPENDIX 19 - Woods Map of 1826 of Darlington**




**APPENDIX 20 - Reeds Map & Schedule of Darlington 1829 (Page 1 of 2)**

**Reed's Map 1829**

**Reed's Schedule 1829**

**APPENDIX 20 - Reeds Map & Schedule of Darlington 1829 (Page 2 of 2)**

| Sheet No | Width (mm) | | | Height (mm) | | | Condition |
|---|---|---|---|---|---|---|---|
| | Top | Cen | Btm | LHS | Cen | RHS | |
| 2A | 893.0 | 892.5 | 894.0 | 567.0 | 568.5 | 570.0 | Sl dirty; sl creased |
| 3A | 901.5 | 898.5 | 896.5 | 564.5 | 565.0 | 565.5 | Sl dirty; sl creased |
| 1B | 896.0 | 895.5 | 895.0 | 570.0 | 569.0 | 568.0 | Sl dirty; sl creased |
| 2B | 894.5 | 894.5 | 894.0 | 563.5 | 565.5 | 567.0 | Sl dirty; sl creased |
| 3B | 892.0 | 891.5 | 891.5 | 564.5 | 565.0 | 565.5 | Sl dirty; sl creased |
| 4B | 889.5 | 890.0 | 891.5 | 565.0 | 566.5 | 566.0 | Slightly dirty |
| 5B | 897.0 | 894.5 | 893.0 | 570.0 | 569.0 | 568.0 | Sl dirty; sl creased |
| 1C | 896.0 | 894.5 | 893.0 | 566.5 | 568.5 | 570.0 | Sl dirty; sl creased |
| 2C | 896.0 | 896.0 | 896.0 | 569.5 | 568.5 | 567.5 | Clean; sl creased |
| 3C | 893.5 | 892.3 | 892.0 | 565 | 565.5 | 565.5 | Creased horiz. |
| 4C | 891.5 | 890.0 | 890.0 | 564.5 | 565.5 | 565.5 | Worn, creased horiz. fair |
| 5C | 889.0 | 887.5 | 885.0 | 566.0 | 565.5 | 563.5 | Worn, creased, dirty |
| 6C | 894.0 | 894.5 | 895.0 | 568.0 | 569.5 | 570.0 | Creased, dirty |
| 2D | 896.0 | 893.5 | 892.0 | 570.0 | 568.5 | 566.5 | Sl dirty; sl creased |
| 3D | 897.2 | 895.5 | 894.0 | 567.1 | 567.0 | 567.5 | Good |
| 4D | 892.5 | 890.0 | 888.5 | 564.5 | 564.8 | 564.5 | Worn, dirty, creased horiz. |
| 5D | 890.0 | 889.0 | 887.0 | 567.5 | 568.0 | 568.5 | Very clean, good |
| 6D | 894.5 | 894.5 | 895.0 | 567.0 | 568.5 | 567.0 | Very clean, good |
| 3E | 894.5 | 896.0 | 896.0 | n/a | n/a | n/a | Sl dirty; sl creased |
| 4E | 893.5 | 892.5 | 892.0 | n/a | n/a | n/a | Sl dirty, creased |
| 5E | 890.0 | 887.5 | 896.5 | n/a | n/a | n/a | Clean; sl creased |
| 6E | 894.5 | 895.0 | 896.0 | 566.5 | 569.0 | 570.5 | Sl dirty; sl creased |

Condition of Original Dmap $^{1852}$ - The Main Grid

| Sheet No | Width (mm) | | | Height (mm) | | | Condition |
|---|---|---|---|---|---|---|---|
| | Top | Cen | Btm | LHS | Cen | RHS | |
| 2F | 893.5 | 894.0 | 895.0 | 567.0 | 569.0 | 570.5 | Sl dirty, creased |
| 3F | 885.5 | 887.0 | 889.5 | n/a | n/a | n/a | Sl dirty, creased |
| 4F | 885.0 | 884.0 | 885.5 | n/a | n/a | n/a | Sl dirty, creased |
| 2G | 893.0 | 893.0 | 893.5 | 569.0 | 570.5 | 573.0 | Dirty, creased |
| 3G | 889.0 | 888.0 | 887.0 | 569.5 | 569.5 | 569.5 | Sl dirty; sl creased |
| 2H | 894.0 | 894.5 | 896.0 | 568.0 | 570.5 | 572.0 | Clean, creased |
| 3H | 894.5 | 895.0 | 896.0 | 566.0 | 567.5 | 568.5 | Slightly dirty |
| 21 | 894.0 | 894.5 | 895.0 | 567.0 | 569.0 | 570.5 | Clean, creased horiz. |
| 31 | 894.0 | 892.5 | 891.5 | 566 | 567.5 | 568.5 | Slightly dirty, creased horiz. |

Condition of Original Dmap $^{1852}$ - The Secondary Grid

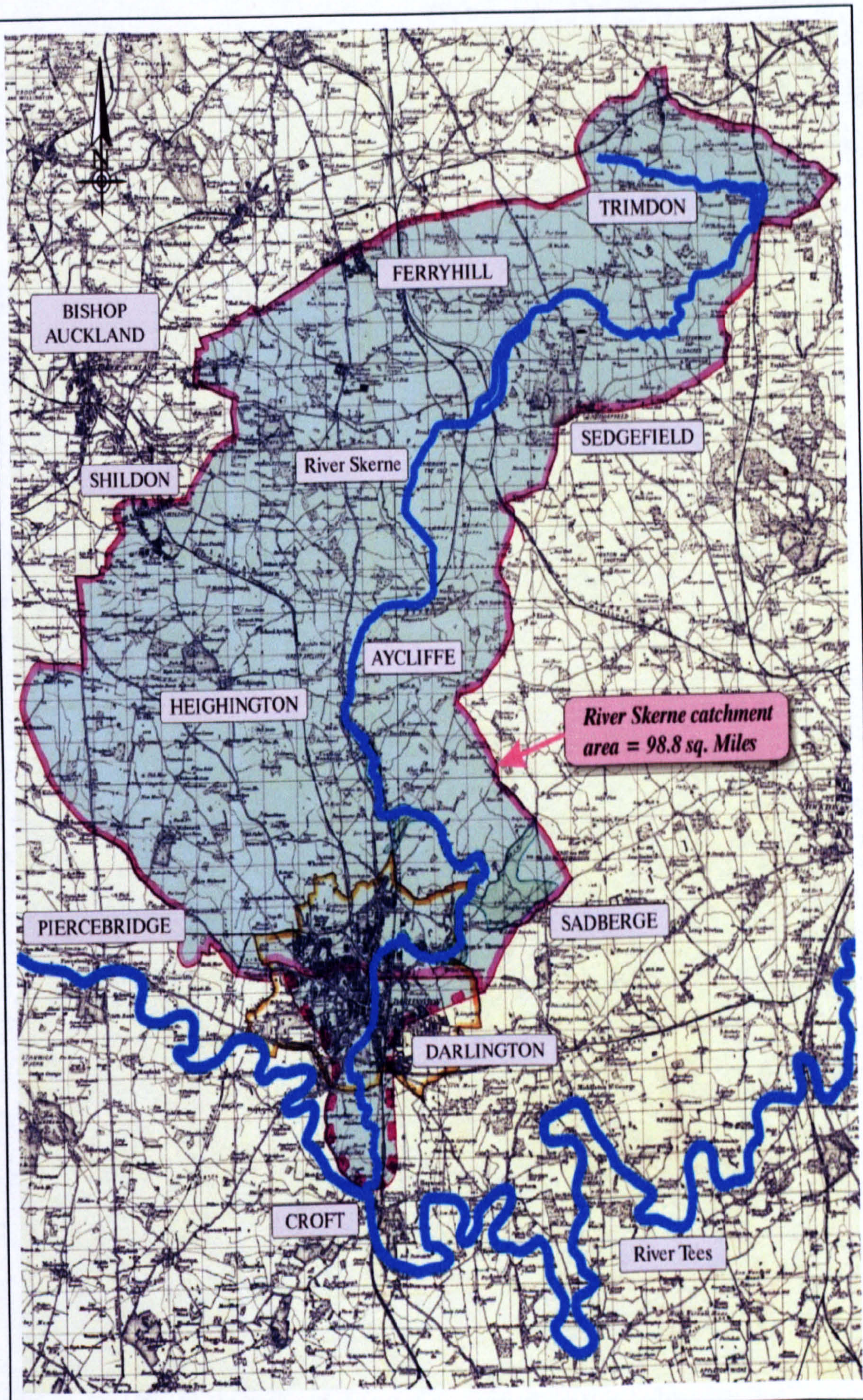
**Note:** Top, Cen, Btm, LHS, RHS as they appear in book form in band from LHS.

## APPENDIX 21 - Schedule of Condition of Dmap $^{1852}$

## SCHEDULE FOR MAP "A" - Outer Darlington

| Place or Vicinity | No on Map | Names of Proprietors | Names of Occupiers | a | r | p |
|---|---|---|---|---|---|---|
| MILL RACE | 508 | Edward Pease | William Kitching | 3 | 0 | 0 |
| " | 509 | " | John Thistlewaite | | 1 | 16 |
| " | 510 | " | Himself | 5 | 0 | 14 |
| " | 511 | " | " | 1 | 0 | 3 |
| " | 512 | " | " | | | 11 |
| " | 513 | " | " | | 3 | 28 |
| " | 514 | " | " | 2 | 1 | 0 |
| " | 515 | " | Henry Thompson | 2 | 2 | 29 |
| " | 516 | " | Anthony Thistlewaite | | | 32 |
| " | 517 | " | " | 1 | 0 | 17 |
| TILE SHEDS | 518 | William Allan Esq. | Ralph Smith | 2 | 1 | 33 |
| " | 519 | " | Ralph Child | 2 | 3 | 24 |
| " | 520 | " | Ralph Smith | 3 | 2 | 23 |
| " | 521 | " | " | 3 | 2 | 38 |
| " | 522 | Sarah Wharton | Thomas Chilton | 3 | 1 | 25 |
| " | 523 | " | " | 2 | 2 | 36 |
| " | 524 | " | " | 2 | 1 | 10 |
| " | 525 | " | " | | 2 | 25 |
| " | 526 | " | " | 7 | 0 | 20 |
| " | 527 | " | " | | 3 | 35 |
| " | 528 | Railway Company | Themselves | | 2 | 11 |
| HUNDONS | 529 | Sarah Wharton | Thomas Chilton | 4 | 1 | 10 |
| " | 530 | " | " | 3 | 1 | 38 |
| " | 531 | " | " | 2 | 3 | 35 |
| " | 532 | " | " | 7 | 1 | 4 |
| " | 533 | " | " | 4 | 1 | 28 |
| " | 534 | William Allan Esq. | John Crawford | 4 | 0 | 39 |
| " | 535 | " | " | 5 | 0 | 21 |
| " | 536 | William Colling | Thomas Crawford | 3 | 1 | 1 |
| " | 537 | " | " | 2 | 1 | 34 |
| " | 538 | Richard Hodgson | George Hinde | 1 | 3 | 14 |
| " | 539 | " | " | 1 | 2 | 9 |
| " | 540 | " | " | 3 | 0 | 13 |
| " | 541 | " | " | 3 | 3 | 37 |
| " | 542 | Sarah Wharton | Thomas Chilton | 5 | 2 | 17 |
| " | 543 | Richard Hodgson | George Hinde | 3 | 3 | 38 |
| " | 544 | Road | George Hinde | 1 | 1 | 27 |

| Cross Sections and Stations | Chainage | | Levels (m) | | | Flood 1875 | Flood 1903 | Flood 1913 | Flood 1941 | Flood 1946 | Flood 1947 | Flood 1949 | Flood 1950 | Flood 1959 | Flood 1963 | Flood 1978 | Design Flood 1952 | Design Flood 1964 | Design Flood 1968 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ft | m | Bed | Embankment RH Bk | Embankment LH Bk | | | | | | | | | | | | | | |
| | 21360 | 6510.53 | | | 39.81 | | | | | | | | | | | | | | |
| | 21400 | 6522.72 | 35.23 | 38.10 | | | | | | | | | | | | | | | |
| | 21500 | 6553.20 | 35.84 | 38.10 | | | | | | | | | | | | | | | |
| Russell St Bridge D/S | 21565 | 6573.01 | | 39.87 | 39.87 | | | 37.55 | | | | | | | | | | | |
| CS67 Russell St Bridge | 21609 | 6586.42 | 35.81 | 39.87 | 39.62 | 39.93 | 37.60 | 37.65 | 37.56 | | | | 37.49 | 37.73 | 37.64 | | 37.89 | 38.31 | |
| 1903 Flood @ Weir | 21639 | 6595.57 | | | | | 39.43 | | | | | | | | | | | | |
| 1903 Flood @ Weir | 21639 | 6595.57 | | | | | 37.64 | | | | | | | | | | | | |
| | 21649 | 6598.62 | 35.81 | 38.19 | | | | | | | | | | | | | | | |
| Weir 1946-1947 Flood * | 21667 | 6604.10 | | | | | | | | 38.81 | 39.10 | | | | | | | | |
| Weir | 21679 | 6607.76 | 37.16 | 38.19 | | | | 39.07 | | | | | 38.97 | 38.95 | 39.01 | | | | |
| Weir Crest * | 21679 | 6607.76 | 37.92 | 39.62 | 39.62 | | | | | | | | | | | | | 39.41 | 39.01 |
| | 21814 | 6648.91 | 36.45 | | | | | | | | | | | | | | | | |
| Chain 1947 | 21966 | 6701.33 | | | | | | | | | 39.13 | | | | | | | | |
| CS68 | 21992 | 6703.16 | 36.76 | 39.62 | 39.62 | | | | | | | | | | | | 39.32 | | |
| Chain 1946 | 22086 | 6731.81 | | | | | | | | 38.86 | | | | | | | | | |
| | 22150 | 6751.32 | 37.34 | | | | | | | | | | | | | | 39.47 | | |
| CS69 | 22307 | 6799.17 | 37.37 | 39.62 | | | | | | | | | | | | | | | |
| Chesnut St D/S | 22385.5 | 6823.10 | | 40.75 | 40.75 | | 39.58 | 39.19 | | 38.96 | 39.11 | | | | | | | 39.84 | |
| Chesnut Stt U/S | 22427 | 6835.75 | 36.52 | 40.90 | 40.90 | | | 39.26 | | 39.11 | 39.21 | | 39.16 | 39.14 | 39.26 | | 39.62 | 39.87 | 39.75 |
| | 22500 | 6858.00 | 37.25 | | 40.08 | | | | | | | | | | | | | | |
| CS70 | 22600 | 6888.48 | 37.06 | | | | | | | | | | | | | | 39.75 | | |
| Chain 1946-1947 | 22664 | 6907.99 | | | | | | | | 39.33 | 39.71 | | | | | | | | |
| | 22680 | 6912.86 | 37.40 | | 40.05 | | | | | | | | | | | | | | |
| | 22800 | 6949.44 | 37.34 | | 39.96 | | | | | | | | | | | | | | |
| Cocker Beck (CS71) | 22970 | 7001.26 | 37.95 | 40.84 | 40.17 | | | 39.93 | 41.09 | 39.50 | 40.08 | | 39.82 | | | | 40.11 | | |
| | 23080 | 7034.78 | 38.25 | | 40.17 | | | | | | | | | | | | | | |
| | 23160 | 7059.17 | 38.31 | 40.11 | 40.54 | | | | | | | | | | | | | | |
| Browns Overflow 1946-1947 | 23210 | 7074.41 | | | | | | | | | 40.35 | | | | | | | | |
| 1903 Flood | 23231 | 7080.81 | | | | | 40.75 | | | | | | | | | | | | |
| Chain 1946 | 23235.5 | 7082.18 | | | | | | | | 39.86 | | | | | | | | | |
| CS72 | 23320 | 7107.94 | 38.28 | 40.17 | 40.60 | | | | | | | | | | | | 41.03 | | |
| John St Bridge D/S | 23395.5 | 7130.95 | | 40.84 | 40.84 | | 41.03 | 40.42 | | | 40.62 | | | | | | | | |
| John St Bridge U/S | 23438 | 7143.90 | 38.16 | 40.29 | 41.54 | 41.39 | 41.06 | 40.73 | 41.01 | 40.00 | 40.65 | | 40.23 | 40.45 | 40.63 | 40.74 | 41.06 | 41.36 | 40.90 |




**APPENDIX 24 - River Skerne Catchment**

**Northern Echo 19th and 20th October, 1875 (Flood 1875 (1))**

*... in the low lying streets on the banks of the River Skerne ...*

*... one of the first places it entered at the north of the town was Darlington Gas Works.*

*... about twelve houses in John Street more or less flooded.*

*... the Cocker Beck, and burst over and flooded Peaceful Valley ...*

*... the left bank of the Skerne, reaching from Freeman's Place to Victoria Road. Very few houses between these points escaped, the water varying in depth from nearly three feet to three inches. In Clay Row, Parkgate, Church Street, Chapel Street, Bridge Street, and the new streets in the vicinity, the water was, of course, the deepest, but Park Street, Low Park Street, Park Place and Model Place, with their intersecting streets had complete currents of water flowing through the houses.*

*... between Parkgate and the Stone Bridge, the footpaths and the road being under water ...*

*... after passing Victoria Bridge, spread over the low-lying fields between that point and the park ...*

*At the park, the water was higher than the bridge, and the footpaths from the bridge were all under water ...*

***Parkgate***

*... the water was then covering the street.*

*... whilst there was no house or shop which escaped the water, from Mr Cairn's on the bridge to Miss Wilson's near Mr Child's tannery entrance. Mr Cairns had about two inches of water in his shop ...*

*... on the bridge, whose house abuts on the river, the water came through the kitchen window.*

*On the other side of the bridge, the water got up to Mr Dalton's ropery ...*

*The water covered the whole of the district east of Hargreave terrace, Including Parkgate, Park street, Park place and Model place, Bridge street, Chapel street, and Backhouse street. In New Park street the water lingered, and there were 60 houses from which the Inmates were unable to come at midday; whilst in Backhouse street, closer to the river, there were 21 families unable to get out till two o'clock.*

***Victoria Road***

*... houses in the Victoria road from the end of Park street to the row of houses on the west of Feethams, were flooded.*

***Messrs Peases' Mills***

*The flood continued up Clay row and the streets adjoining towards Peaceful Valley, and in its course visited the Priestgate Mills of Messrs Pease.*

***Incidents of the Flood***

*... the flooded field by Feethams ...*

*... some yards in John Street ...*

***Cockerton***

*The new bridge over Cockerbeck was submerged.*

**Northern Echo 15th November, 1875 (Flood 1875(2))**

***Darlington Again Flooded***

*... a second flood which has wrought even greater destruction than its predecessor in October.*

*There are hundreds of houses along the Skerne side which have four and five feet of water in them ...*

*Great Floods in the North*

*Darlington, Croft and Stockton Inundated*

*In the great flood of the 21st October, when Darlington was flooded by the Skerne, the Tees rose very little above its usual level, but yesterday the Tees came down like a Highland torrent in spate ...*

*... when it passed the pumping stations near Tees Cottage, the volume of water was great ...*

*Above the bridge over the Skerne, before it enters the Tees, the river bed was entirely filled, but, fortunately, the water kept within bounds, and the only flooding resulted from surface water. At the bridge, an overflow took place, which caused the road and the adjoining land to become submerged. Nothing was to be seen of the Skerne, Tees, or bridge, but a wide expanse of water. From the Croquet Grounds to the Baths was a sheet of water of two to three feet deep, and the road, as far as the Nag's Head, was covered to a depth of several feet.*

*The houses in the vicinity had their ground floors inundated ...*

*... the water extending from the church up to houses on the opposite bank.*

*... the railway being flooded was witnessed.*

*... water collected beneath the bridge and in front of the station to the depth of a couple of feet.*

*... but the water was kept on the permanent way.*

*... a considerable extent of the Hurworth road was also submerged.*

*The heavy rainfall had converted almost every hollow in the fields into a lake, and in the meadow land, the depressions between each rig were filled with water.*

*At some places on the great south road, the water was so deep as almost to be impassable.*

*The whole of the valley above and below Blackwell Mill was one vast lake. Blackwell Mill itself stood on the extreme margin of the flood.*

*At the Park, the waters came up to the bridge, and flooded the road on the south side of the river ...*

*Between the Park Bridge and the railway bridge at the far end of Northgate, there stretched a sheet of water from 200 yards to a quarter mile in breadth, crossed here and there by bridges - all submerged ...*

*... except the Stone Bridge and Victoria Bridge ...*

*Between the Park and Victoria Road there lay a large lake ...*

*... standing in five or six feet of water ...*

*Mr Spence's nursery gardens were again flooded, and the Skerne had covered the cricket fields.*

*... to the north, the inundations flooded streets, whereas to the south it only submerged fields. Victoria Bridge was the boundary between the two.*

*... from the Gasworks to Victoria Road ...*

*... rushing over all the bridges ...*

*... excepting the Stone Bridge and Victoria Bridge ...*

*On the north side of the river, all the streets, from John Street to Russell Street, were all more or less under water at one end.*

*From the point where the road rises to Haughton to where it rises to Victoria Road, Darlington was a miniature plebeian Venice. The water in Parkgate varied in depth from three to four feet. Towards Haughton Road it increased in depth until it was too deep for horses to cross.*

*In the Central Hall, rooms were got ready for the 'reception' of those rescued from the flood ...*

*Between Russell street Bridge and the Stone Bridge, several outhouses were swept away ...*

*... the low side of the Lead-yard Bridge a considerable length of wall was washed down. The foot bridge at the foot of North Lodge gardens was swept away ...*

*... current, which was running from five to six feet deep. Along the Haughton road, the water varied in places from five to as much as ten feet in depth.*

*The low mill at Priestgate was inundated ...*

*At the Lead-yard, the yard of the Jubilee School - the old Grammar School - was so full of water that no school could be held last ...*

*... and that there was fully two feet more water than in the October flood.*

*The Cocker Beck, which empties itself into the Skerne, after passing through Westbrook, was flooded beyond all precedent.*

*... through Cockerton it overflowed its banks, covered the green up to the school-house, submerged the bridge to Archdeacon Newton ...*

*On entering the town, the beck still overflowing its banks, ran like a river over Westbrook across Northgate, through the Baptist Chapel and into the Skerne.*

*... entered the sour of the Westbrook new buildings.*

**Northern Echo 16 November, 1875 (Flood [1875(2)])**

***The Floods***

***The North-Eastern Main Line Damaged***

***Traffic Suspended for Nine Hours***

*Messrs Pease's mill below the Gasworks, was also seriously inundated ...*

*The lower ends of the streets in this vicinity had been seriously flooded on Sunday, and in Lambton street the bottom house on the side nearer the town was cracked ...*

*... water rushed over and devastated 'Peaceful Valley'.*

*... the current, which had previously rushed down Mount street, East street, Clay row etc fell back into the confines of Peaceful Valley, and discharged itself into the Skerne at Russell Street Bridge. That portion of Valley Street below the Bridge seemed also to have suffered severely. The houses were inundated to an alarming extent ...*

*In Clay Row from depressed position, the water lay during the whole of the day ...*

*The water flowing from Peaceful Valley traversed the streets ...*

*Church street, Parkgate and Park street were inundated more or less. Skerne row ...*

*Between Backhouse street and the river the outhouses were flooded ...*

*In Park street, the water stood up over the door-steps in front of many of the houses ...*

*In Parkgate several tradesmen suffered severely.*

*Along both sides of the river gardens were wrecked ...*

*The Park Bridge has gone by the bridge.*

**APPENDIX 25 - Extracts from Newspaper Articles (Page 7 of 7)**

| Reference | Drg No 1 [No 402] | Drg No 2 [No 403] | Drg No 3 [No 404 | Drg No 4 [No 403 |
|---|---|---|---|---|
| Title | Section : S & DR$^{Y}$ Bridge to Oxneyfield Bridge | Plan : S & DR$^{Y}$ Bridge to Victoria Road | Plan : Victoria Road to Blackwell Mill | None given |
| Scales | H :<br>V : 10 ft to 1 in | 44 ft to 1 in<br>[presented in chains/ links and feet] | 44 ft to 1 in<br>[presented in chains/ links and feet] | 10 ft to one in<br>[natural] |
| Dimension | 96" x 12¼"<br>[2440mm x 325mm] | 115¼" x 25¾"<br>[2925mm x 655mm] | 106½" x 27⅞"<br>[2705mm x 658mm] | 47½" x 26¾<br>[1205mm x 680mm] |
| Description | A detailed longitudinal section from S & DR$^{Y}$ Bridge showing:<br>• The existing features, including bridges and bed levels.<br>• Flood line of the 14th November 1875.<br>• Probable future highest flood level.<br>• Proposed new river bottom.<br>• Location and height of proposed weirs.<br>• Indication of various gradients:<br>⇒ S & DR$^{Y}$ Bridge to Leadenhall Bridge 13½ ft/mile<br>⇒ Leadyard Bridge to Proposed Weir [No 3] 7.4 ft.mile<br>⇒ Proposed Weir [No 3] to Oxneyfield Bridge 8.5 ft/mile | A very large plan showing:<br>• The existing line of the River as surveyed from S & DR$^{Y}$ Bridge to Victoria Bridge.<br>• Improvement line:<br>⇒ S & DR$^{Y}$ Bridge to John Street with new River Walls.<br>⇒ John Street to 'Mount Street Watercourse' - opposite Russell Street incorporating:<br>◊ A 250' weir opposite Lambton Street to Leadenhall Street.<br>◊ Realignment of Cocker Beck confluence with new walls terminating with a 50' wide weir to the River Skerne.<br>◊ River Walls to the River Skerne.<br>• General Improvement to alignment between Russell Street to Priest Gate - widening and provision of River Walls.<br>• Part River Walls and new 190' wide weir across River from 'Factory' and Stone Bridge.<br>• General improvement to alignment between Leadenhall Bridge to Victoria Bridge - widening and provision of River Walls. | A very large plan showing:<br>• The line of the River as surveyed with improvement lines from Victoria Bridge to Polam Bridge. Further improvements on a new line from The Park Bridge downstream of Blackwell Mill, with a large weir [300 ft.] opposite a Bywash.<br>• Between Polam Bridge and The Park Bridge a further improvement line and the existing line is noted to the effect 'River to be made of the full sectional area shown on Cross Section ❶. The Cross Section is given for the new line improvements with a 44'0" wide bed, side slopes of 1 to 1, a flat top of embankment with a further burm of1⅓ to 1 slopes. Harrison estimated that the *'probable future highest flood level'* would be 10 ft above the River bed. | A series of Cross Sections of the River and Bridges at the following locations:<br>• S & DR$^{Y}$ Bridge<br>• John St Bridge<br>⇒ To be widened 9 ft<br>⇒ To be deepened 2 ft<br>• Russell Street Bridges<br>⇒ Over River - to be widened 15½ ft<br>⇒ Over Mill Dam<br>• East St Bridge<br>⇒ To be widened 8 ft<br>⇒ To be deepened 3 ft<br>• Gas Works Bridge<br>⇒ To be deepened 4 ft<br>• Priest Gate Bridge<br>⇒ To be raised 1 ft<br>⇒ To be deepened 2 ft?<br>• Stone Bridge<br>⇒ To be deepened 3'9"<br>• Leadyard Bridge<br>⇒ To be deepened 2'6"<br>• Victoria Bridge<br>⇒ To be deepened 3'6" |

## APPENDIX 26- Engineering Information

**Graham (1975)**

*The bridge across the Skerne here existed in early times, being mentioned in 1299 and 1343. In 1299 the wardrobe book of Edward 1 mentions that £2.5s.2d. was paid for repairs to make the bridge safe for wagons conveying the king's treasure. Leland says, 'Darlington Bridge of Stone, is, as I remembre, of three arches'. The medieval bridge was replaced, possibly in 1587, by one with nine arches, because the Calendr o Border Papers records in that year the expenditure of £62.2s.8d. on Darlington Bridge while two years previously Thomas Elstob of Darlington left what was then the large sum of 3s. 4d. 'towards the mendinge of Skerne Brigg, which is at the east end of the churche to be payde when it is amendinge.'*

*Defoe described this bridge in 1727 as 'a high stone bridge over little or no water'. The river then was very wide and shallow. The print we reproduce was from a drawing made in 1760 by A. Wilkinson. In 1767 a new bridge was built alongside, consisting of three plain arches, and the old one demolished. All these bridges stood at the foot of Tubwell Row (which is called Briggate by the historian Hutchinson).*

*Longstaffe, the historian of Darlington, also mentions a narrow brick bridge, two miles below the town and called Nought or Snipe Bridge. It had two arches and was built at a cost of £20 in 1698 to replace a timber bridge on stone piers.*

**APPENDIX 27 - Extracts from Published References on Flooding**

| Plan No & Date | Description | Scale |
|---|---|---|
| BEng 40.2<br>9 March 1876 | No 1 Skerne Flooding<br>Section from S & DR$^{Y}$ Bridge to Oxneyfield Bridge | H 3" : 1 inch |
| BEng 412/1<br>Date c1904 | River Skerne<br>Longitudinal section<br>John Street to Blackwell Mill | H 120' : 1 inch<br>V 10' : 1inch |
| BEng No 898<br>B Eng No 3105/3<br>BEng No 3105/4<br>Date c1933 | Proposed Regrading of River Skerne<br>Plans and Sections | H 1 : 2500<br>V 10' : 1 inch |
| BEng No 898<br>BEng No 3105/5 | Proposed Regrading of River Skerne<br>Plans and Sections | H 1 : 2500<br>V 10' : 1 inch |
| BEng No 994<br>BEng No 0/1/2<br>Date c1933 | River Skerne<br>Longitudinal Section showing Flood Levels 27 February 1933 | H 6" : 1m<br>V 10' : 1 inch |
| BEng 208/1<br>Mar 1936 | Proposed Regrading of River Skerne<br>Longitudinal Section<br>Russell Street & Albert Road Bridge | H 1 : 500<br>V 10' : 1" |
| BEng 3105/1<br>8 Mar 1941 | Mapof the County Borough of Darlington<br>Maximum Flood Levels 26/27 Feb 1941 | 6" : 1m |
| BEng 898A<br>Unknown | River Skerne<br>Longitudinal Section<br>John Street Bridge to Russell Street Bridge | H 1 : 500<br>V 10' : 1" |
| BEng 2081/6<br>22 June 1949 | County Borough of Darlington<br>River Skerne Re-grading<br>Cross Sections | H 10' : 1"<br>V 10' : 1" |
| BEng 2081/8<br>16 Aug 1949 | County Borough of Darlington<br>River Skerne Re-grading<br>Areas liable to flooding | 6" : 1m |

**APPENDIX 28- Schedule of Drawings Referred to (Sheet 1 of 2)**

| Plan No & Date | Description | Scale |
|---|---|---|
| WTRB S/8·387?<br>BEng 2081/21/01 | River Skerne Survey<br>Cross Sections CS12 & 15-22 | H & V<br>10' : 1" |
| WTRB S/8·261<br>BEng 2081/26<br>22 Jul 1952 | River Skerne General Imp Scheme - Part 2<br>Cross Sections<br>South Park to Feethams | H & V<br>10' : 1" |
| WTRB S/8·265<br>BEng 2081/26<br>24 Jul 1952 | River Skerne General Imp Scheme - Part 2<br>Bridge Details<br>From chainage 0-22,500 | H & V<br>10' : 1" |
| WTRB S/8·262<br>BEng 2081/34<br>25 Jul 1952 | River Skerne General Imp Scheme - Part 2<br>Cross Sections<br>Feethams to John Street | H & V<br>10' : 1" |
| WTRB S/8·263<br>BEng 2081/35<br>20 Oct 1953 | River Skerne General Imp Scheme - Part 2<br>Cross Sections<br>Gasworks - Wire Mills | H & V<br>10' : 1" |
| WTRB S/8·...<br>BEng 2081/38<br>20 Oct 1953 | River Skerne General Imp Scheme - Part 2<br>Bridge Details<br>Gasworks - Great Burdon Bridge | H & V<br>10' : 1" |
| WTRB S/8·259<br>BEng 2081/26<br>20 Oct 1952 | River Skerne General Imp Scheme - Part 2<br>Cross Sections<br>South Park Weir to Geneva Road Bridge | H & V<br>10' : 1" |
| WTRB .....<br>BEng 2081/26<br>c1953 | River Skerne General Imp Scheme - Part 2<br>Longitudinal Section<br>South Park Weir to Five Arch Bridge | H 200' : 1"<br>V 10' : 1" |
| WTRB ..·...<br>BEng 2081/26<br>c1953 | River Skerne General Imp Scheme - Part 2<br>Longitudinal Section<br>Five Arch Bridge to Great Burdon Bridge | H 200' : 1"<br>V 10' : 1" |
| WTRB ....<br>BEng 2081/26 | River Skerne Improvement Scheme<br>Longitudinal Section<br>South Park Weir to Main Line Railway Bridge | H 200' : 1"<br>V 10' : 1" |
| WTRB<br>S/1/15·2927<br>BEng 2081/46 | WTRB - River Skerne<br>Longitudinal<br>Victoria Road Bridge - Albert Road Bridge | H 100' : 1"<br>V 10' : 1" |
| NRA 130/3/9/3<br>BEng 3837/13<br>October 1969<br>NRA 130/3/9/6<br>BEng 3837/14<br>May 1970 | River Skerne at Darlington<br>Proposed Channel Improvement<br>Cross Sections from Russell Street Bridge | H & V<br>10' : 1" |
| BEng 3105/15 | Borough of Darlington<br>Flood Levels 28 December 1978 | 6" : 1m |

## APPENDIX 28- Schedule of Drawings Referred to (Sheet 2 of 2)

***Borough Surveyor and Waterworks Engineer's Office,***
***29th February, 1904***

*To the Chairman and Members of the Streets Committee.*

*Gentlemen,*

*In accordance with your instructions that I should report on the best means to be adopted to prevent, as far as possible, the flooding of the low-lying streets in the Borough adjoining the river, I have pleasure in submitting for your consideration the following particulars relating to the levels of the river in its normal condition and when in flood, and also my recommendations thereon.*

*From the plans and sections accompanying this report it will be seen that there are six weirs between Blackwell Mill and John Street, and the difference in level between the top and bottom of each is as follows, viz:-*

| | | FT. | IN. | | | FT. | IN. |
|---|---|---|---|---|---|---|---|
| 1. | Blackwell Mill .. .. | 8 | 9 | 4. | Leadyard Bridge .. | 1 | 9 |
| 2. | South of Park .. .. | 6 | 0 | 5. | Russell Street .. .. | 8 | 9 |
| 3. | In Park .. .. .. | 2 | 3 | 6. | John Street .. .. | 3 | 0 |

*The object of the weir at Blackwell Mill and the one at the south of the Park is to dam the water in the river during the night in dry weather so that there may be sufficient water during the day to drive the water wheel at Blackwell Mill.*

*The weir in the Park was constructed in connection with the straightening of the Skerne for the purpose of lowering the water level during flood time, and thereby increasing the velocity of the river between that point and the weir at the Leadyard.*

*The weir at the Leadyard Bridge is for the purpose of retaining sufficient water during dry weather to cover the whole of the bed of the river between that point and Russell Street Bridge.*

*The weirs at Russell Street and John Street are required to dam the water for driving the water wheel at Priestgate Mill. I may mention that the weir at John Street was raised 18 inches about 18 years ago, and since then the water way below the weir has been very much contracted, so that at the present time the flood water falling over the weir has to pass through a culvert, which is only nine feet in width and six feet in height.*

*The levels of the top of the weirs above ordnance datum are as follows:-*

*The Park, 114.78; Leadyard, 116.69; Russell Street, 126.17; John Street, 130.47.*

*During the last flood the water level at Priestgate Bridge was 124.62, which is 15 inches above the street level in Clay Row, and three inches above the street level in Parkgate opposite St. Hilda's Church. Whilst the flood level in John Street was two feet below the flood level in the river at the Bridge.*

*The flooding of Parkgate and Clay Row is caused by water rising out of the sewer gratings, this can only be prevented by lowering the flood level in the river, as the self-acting storm water outlets from the sewers can only discharge at river water level, therefore when the river rises above the level of the manhole gratings the water in the sewers is forced into the streets. Nothing can be gained by increasing the number or size of the storm water outlets, as the sectional area of the 11 existing outlets is 33 feet, which is 20 feet larger than the sectional area of the main sewer.*

*The flooding of John Street is caused by the river overflowing the bridge, and not from the main sewer, which relieves itself by discharging at a lower level below the weir at Russell Street.*

*After careful consideration of the whole question I would recommend -*

1. *That the present weirs at the Park and Leadyard Bridge be removed and wooden movable weirs be substituted.*

2. *That the stone weir at Russell Street be lowered two feet, and a movable weir substituted. Also that the existing two sluices in connection with this weir, with a total sectional area of 60 feet, be opened during flood time.*

3. *That the weir at John Street be lowered 18 inches to its original level.*

*I am satisfied that the effect of the above alterations would be to lower the flood level at Parkgate, Clay Row, and John Street from 12 to 15 inches, and the level of the water in the sewers to a corresponding level.*

*The approximate cost of carrying out the alterations would be as follows:-*

| | £ | s. | d. |
|---|---|---|---|
| *Alterations to Weir at the Park .. .. ..* | *100* | *0* | *0* |
| *Alterations to Weir at Leadyard .. .. ..

*Accompanying this report is a model showing the working of the movable weirs at flood time.*

*Yours obediently,*

*GEORGE WINTER.*

*Borough Surveyor's Office*

*29 February, 1904.*

**APPENDIX 29 - George Winter's Report, 1904 (Page 3 of 3)**

APPENDIX 30 - Sample of Gypsum with Dissolution Karen Surface

| BILL NO. 1 | | | | | |
|---|---|---|---|---|---|
| **Item** | **Description** | **Unit** | **Qty** | **Rate** | **£** |
| **A** | **General Items and Provisional Sums** | | | | |
| A1 | Offices and stores for the Contractor | sum | | | 10290 |
| A2 | Establish on site all plant, equipment and services | sum | | | 111250 |
| A4 | Establish the location and elevation of the ground at each exploratory hole | sum | | | 41160 |
| A5 | Facilities for the Engineer | sum | 0.0 | | 0 |
| A6 | Vehicles for the engineer | wk | 0.0 | | 0 |
| A8 | Engineer's telephone and facsimile charges | prov sum | 0.0 | | 0 |
| A9 | Deliver selected cores and samples to the specified address | prov sum | | 60.00 | |
| A10 | Special testing and sampling required by the Engineer | prov sum | | 1000.00 | |
| A11 | Traffic safety and management | sum | | | 10290 |
| A12 | One master copy of the Factual report | sum | | | 72030 |
| A13 | Additional copies of the Factual report | nr | 823 | 20.00 | 16464 |
| A14 | One master of the Interpretative report | sum | | | 102900 |
| A15 | Additional copies of the Interpretative report | nr | 823 | 20.00 | 16464 |
| A16 | Report in AGS digital format | sum | | | 20580 |
| A17 | Photographs of trial pits | nr | 1550 | 10.00 | 15500 |
| A18 | Requirements of BDA yellow site | sum | | | 10290 |
| A19 | Reinstatement of tarmac surface | m2 | 257 | 45.00 | 11576 |
| 1 | Engineering geologist | day | 412 | 175.00 | 72030 |
| | | | | Total Carried to Summary £ | 510824 |

## BILL NO. 2

| Item | Description | Unit | Qty | Rate | £ |
|---|---|---|---|---|---|
| **B** | **Boreholes** | | | | |
| B1 | Move boring plant and equipment to the site of each exploratory hole and set up | nr | 620 | 25.00 | 15500 |
| B2 | Extra over Item B1 for setting up on a slope of gradient greater than 20% | nr | 0 | 0.00 | 0 |
| B3 | Break out surface obstruction where present at exploratory borehole | h | 310 | 25.00 | 7750 |
| B4 | Advance borehole between existing ground level and 10 metres | m | 6198 | 12.00 | 74377 |
| B5 | As Item B4 but between 10 m and 20 m depth | m | 4203 | 14.00 | 58838 |
| B6 | As Item B4 but between 20 m and 30 m depth | m | 1469 | 17.00 | 24967 |
| B7 | As Item B4 but between 30 m and 40 m depth | m | 566 | 20.00 | 11319 |
| B9 | Advance borehole through hard stratum or obstructions | h | 620 | 25.00 | 15500 |
| B10 | Backfill borehole with cement/bentonite grout | m | 12435 | 8.00 | 99483 |
| B11 | Standing time for borehole plant, equipment and crew | h | 620 | 25.00 | 15500 |
| | | | | Total Carried to Summary £ | 323234 |

| BILL NO. 3 | | | | | |
|---|---|---|---|---|---|
| **Item** | **Description** | **Unit** | **Qty** | **Rate** | **£** |
| **C** | **Rotary Drilling** | | | | |
| C1 | Move rotary drilling plant and equipment to the site of each exploratory hole and set up | nr | 409 | 50.00 | 20450 |
| C2 | Extra over Item C1 for setting up on a slope of gradient greater than 20% | nr | 0 | 0.00 | 0 |
| C4 | Break out surface obstructions where present at each exploratory drillhole | h | 205 | 50.00 | 10225 |
| | *Drilling without cores* | | | | |
| C5 | Rotary drill in materials other than hard strata at 119 mm dia, from which cores are not required, between existing ground level and 10 m depth | m | 4090 | 12.00 | 49080 |
| C6 | As Item C5 but between 10 m and 20 m depth | m | 4090 | 14.00 | 57260 |
| C7 | As Item C5 but between 20 m and 30 m depth | m | 4090 | 16.00 | 65440 |
| C8 | As Item C5 but between 30 m and 40 m depth | m | 4090 | 18.00 | 73620 |
| | *Drilling to obtain cores* | | | | |
| C22 | Rotary drill in hard strata to obtain cores of 76 mm dia (H) starting at bottom of open hole between 40 m and 50 m depth | m | 8254 | 75.00 | 619051 |
| C23 | As Item C22 but between 50 m and 60 m depth | m | 7117 | 80.00 | 569397 |
| C24 | As Item C22 but between 60 m and 70 m depth | m | 5996 | 85.00 | 509627 |
| C25 | As Item C22 but between 70 m and 80 m depth | m | 5207 | 90.00 | 468607 |
| C26 | As Item C22 but between 80 m and 90 m depth | m | 3542 | 90.00 | 318794 |
| C27 | As Item C22 but between 90 m and 100 m depth | m | 3290 | 90.00 | 296126 |
| C28 | As Item C22 but between 100 m and 110 m depth | m | 2635 | 90.00 | 237116 |
| C29 | As Item C22 but between 110 m and 120 m depth | m | 1598 | 90.00 | 143819 |
| | | | | Carried Forward £ | 3438611 |

| BILL NO. 3 (continued) | | | | | |
|---|---|---|---|---|---|
| **Item** | **Description** | **Unit** | **Qty** | **Rate** | **£** |
| | *Drilling to obtain cores - continued* | | | | |
| C30 | As Item C22 but between 120 m and 130 m depth | m | 1372 | 116.00 | 159165 |
| C31 | As Item C22 but between 130 m and 140 m depth | m | 991 | 116.00 | 114915 |
| C32 | As Item C22 but between 140 m and 150 m depth | m | 0 | 116.00 | 0 |
| C33 | As Item C22 but between 150 m and 160 m depth | m | 723 | 116.00 | 83842 |
| C34 | As Item C22 but between 160 m and 170 m depth | m | 564 | 116.00 | 65422 |
| C35 | As Item C22 but between 170 m and 180 m depth | m | 0 | 135.00 | 0 |
| C36 | As Item C22 but between 180 m and 190 m depth | m | 0 | 135.00 | 0 |
| C37 | As Item C22 but between 190 m and 200 m depth | m | 399 | 135.00 | 53822 |
| C38 | As Item C22 but between 200 m and 210 m depth | m | 203 | 135.00 | 27405 |
| C40 | Extra over Item C22 to C26 for use of semi-rigid core liner | m | 41687 | 6.00 | 250122 |
| | *General* | | | | |
| C41 | Backfill drillholes with cement/bentonite grout | m | 41890 | 12.00 | 502681 |
| C42 | Core box to be retained by client | nr | 409 | 15.00 | 6135 |
| C43 | Standing time for rotary drilling, equipment and crew | h | 409 | 50.00 | 20450 |
| C44 | Colour photographs of core | nr | 13963 | 10.00 | 139634 |
| C45 | Casing to rock head | m | 4090 | 6.00 | 24540 |
| | | | Brought forward | | 3438611 |
| | | | Total Carried to Summary £ | | 4886745 |

**BILL NO. 4**

| Item | Description | Unit | Qty | Rate | £ |
|---|---|---|---|---|---|
| **D** | **Pits and Trenches** | | | | |
| | *Inspection Pits* | | | | |
| D1 | Excavate inspection pit by hand to 1.2 m depth | nr | 620 | 30.00 | 18600 |
| D2 | Extra over Item D1 for breaking out surface obstructions | h | 155 | 25.00 | 3875 |
| | *Trial Pits* | | | | |
| D3 | Move equipment to site of each trial pit or trench | nr | 1550 | 25.00 | 38750 |
| D4 | Excavate trial pit between existing ground level and 3.0 m depth | m | 4650 | 5.00 | 23250 |
| D5 | As Item D4 but between 3.0 m and 4.5 m depth | m | 2325 | 8.00 | 18600 |
| D6 | As Item D4 but between 4.5 m and 6.0 m depth | m | 0 | 0.00 | 0 |
| D10 | Extra over Items D4 and D5 for breaking out hard strata or surface obstructions | h | 620 | 30.00 | 18600 |
| D11 | Standing time for excavation plant, equipment and crew for machine dug trial pit | h | 620 | 38.00 | 23560 |
| | | | | Total Carried to Summary £ | 145235 |

| BILL NO. 5 | | | | | |
|---|---|---|---|---|---|
| **Item** | **Description** | **Unit** | **Qty** | **Rate** | **£** |
| **E** | **Sampling** | | | | |
| E1 | Small disturbed sample | nr | 31071 | 1.00 | 31071 |
| E2 | Bulk disturbed sample from boreholes | nr | 6218 | 1.50 | 9327 |
| E3 | Large bulk disturbed sample from pits | nr | 6200 | 1.50 | 9300 |
| E4 | Open tube sample | nr | 6218 | 7.50 | 46633 |
| E6 | Groundwater sample | nr | 2790 | 2.00 | 5580 |
| **F** | **In situ Testing** | | | | |
| F1 | Standard penetration test in borehole | nr | 6218 | 7.50 | 46633 |
| F8 | Hand vane test | nr | 13950 | 1.00 | 13950 |
| **G** | **Instrumentation and Monitoring** | | | | |
| | *Standpipes and piezometers* | | | | |
| G1 | Backfill exploratory hole with cement/bentonite grout below standpipe or standpipe piezometer | m | 868 | 8.00 | 6944 |
| G3 | Standpipe piezometer | m | 868 | 16.00 | 13888 |
| G4 | Gas monitoring standpipe | m | 868 | 20.00 | 17360 |
| G5 | Protective cover (flush) | nr | 124 | 45.00 | 5580 |
| G8 | Reading of water level in standpipe, or standpipe piezometer during fieldwork period | nr | 124 | 20.00 | 2480 |
| G9 | Gas measurement in gas monitoring standpipe during fieldwork period | nr | 124 | 20.00 | 2480 |
| G10 | Reading of water levels 2 weeks after fieldwork | nr | 62 | 50.00 | 3100 |
| G11 | Gas measurement 2 weeks after fieldwork | nr | 62 | 50.00 | 3100 |
| | | | Total Carried to Summary £ | | 217425 |

**BILL NO. 6**

| Item | Description | Unit | Qty | Rate | £ |
|---|---|---|---|---|---|
| **B** | **Laboratory Testing** | | | | |
| *H1* | *Classification* | | | | |
| H1.1 | moisture content | nr | 3100 | 2.00 | 6200 |
| H1.2 | Liquid limit, plastic limit and plasticity index | nr | 1240 | 15.00 | 18600 |
| H1.5 | Density by linear measurement | nr | 1860 | 14.00 | 26040 |
| H1.9 | Particle size distribution by wet sieving | nr | 620 | 17.00 | 10540 |
| H1.12 | Sedimentation by hydrometer | nr | 620 | 25.00 | 15500 |
| *H2* | *Chemical and electrochemical tests* | | | | |
| H2.1 | Organic matter content | nr | 310 | 15.00 | 4650 |
| H2.2 | Mass loss on ignition | nr | 155 | 8.00 | 1240 |
| H2.3 | Sulphate content of acid extract from soil | nr | 620 | 14.00 | 8680 |
| H2.4 | Sulphate content of water extract form soil | nr | 310 | 14.00 | 4340 |
| H2.5 | Sulphate content of groundwater | nr | 310 | 14.00 | 4340 |
| H2.12 | pH value | nr | 1240 | 7.00 | 8680 |
| *H3* | *Compaction Related* | | | | |
| H3.1 | Dry/density moisture content relationship using 2.5 kg rammer | nr | 310 | 30.00 | 9300 |
| H3.9 | California Bearing Ratio on recompacted disturbed sample | nr | 310 | 25.00 | 7750 |
| *H4* | *Compressibility, permeability, durability* | | | | |
| H4.1 | One-dimensional consolidation properties, test period 5 days | nr | 620 | 30.00 | 18600 |
| H4.2 | Extra over Item H4.1 for test period in excess of 5 days | nr | 1240 | 5.00 | 6200 |
| | | | | Carried Forward £ | 150660 |

**BILL NO. 6 continued**

| Item | Description | Unit | Qty | Rate | £ |
|---|---|---|---|---|---|
| *H6* | *Shear strength (total stress)* | | | | |
| H6.17 | Undrained shear strength of a single 100 mm dia specimen in triaxial compression with multistage loading and without measurement of pore pressure | nr | 1860 | 25.00 | 46500 |
| *H7* | *Shear strength (effective stress)* | | | | |
| H7.2 | Consolidated undrained triaxial compression test with measurement of pore pressure (multistage test using 100 mm dia specimen), test duration not exceeding 4 days | nr | 124 | 90.00 | 11160 |
| H7.4 | consolidated drained triaxial compression test with measurement of volume change (multistage test using 100 mm dia specimen), test duration not exceeding 4 days | nr | 124 | 90.00 | 11160 |
| H7.6 | Extra over Items H7.2 and H7.4 for test duration in excess of 4 days | nr | 496 | 20.00 | 9920 |
| *H8* | *Rock Testing* | | | | |
| H8.14 | Uniaxial compressive strength | nr | 818 | 35.00 | 28630 |
| H8.21 | Determination of point load strength of rock specimen | nr | 818 | 5.00 | 4090 |
| **I** | **Chemical testing for contaminated ground** | | | | |
| I1 | ICRCL test on soils | nr | 1860 | 65.00 | 120900 |
| I2 | ICRCL test on water | nr | 620 | 65.00 | 40300 |
| | | | | brought forward | 150660 |
| | | | | Total Carried to Summary £ | 423320 |

| SUMMARY | | | | | |
|---|---|---|---|---|---|
| **Item** | **Description** | **Unit** | **Qty** | **Rate** | **£** |
| | **Brought foreword** | | | | |
| | Bill Number 1 - General Items | | | | 510824 |
| | Bill Number 2 - Boreholes | | | | 323234 |
| | Bill Number 3 - Rotary Drilling | | | | 4886745 |
| | Bill Number 4 - Trial Pits | | | | 145235 |
| | Bill Number 5 - Sampling, In situ Testing and Instrumentation and monitoring | | | | 217425 |
| | Bill Number 6 - Laboratory Testing | | | | 423320 |
| | **Total Cost** | | | | 6506783 |